VOLUME XLIII NUMBER 1

# THE HAWAIIAN PLANTERS' RECORD




Delays in weed control were responsible for these differences in cane growth.

FIRST QUARTER 1939

# HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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# THE HAWAIIAN PLANTERS' RECORD

Vol. XLIII FIRST QUARTER 1939 No. 1

*A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.*

**In This Issue:**

*A Simple Apparatus for the Rapid Determination of Moisture by the Carbide Method:*

A rapid and extremely simple method is described for the determination of soil moisture. The method eliminates drying of the specimen in a heated oven. With a slight additional simplification it may be adapted for rough estimations of soil moisture in the field by using a measuring device to gauge a preselected volume of sample instead of weighing it on a laboratory balance.

The method as described requires but 10 minutes to perform a soil moisture determination.

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*Studies in Experimental Technique:*

The value of laying out field experiments so that their results may be studied by modern refinements of statistical methods is clearly shown in the actual interpretation of the results from a potash experiment.

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*A Pictorial Showing the Effects of Delayed Weed Control Upon Subsequent Growth of Sugar Cane:*

A series of pictures tells a graphic story of the effect of delayed weeding upon the cane which is growing in soils having specific variations in available plant foods.

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*Mineralizable Nitrogen in Some Hawaiian Soils:*

Ninety per cent or more of the reserves of organic soil nitrogen (total nitrogen) are not available to plant life until after "mineralization" takes place. The term "mineralization" implies naturally occurring microbiological changes in the soil in which soil organic nitrogen is transformed to compounds of ammonia and to

nitrates, both of which are capable of immediate utilization by a growing crop. The authors present discussion and data in plain terms supporting the premise that organic soil nitrogen is readily mineralizable under favorable conditions. Their laboratory determination of this property is described. (It is adaptable to R. C. M.) Definitions of terms are given fully. The authors point out the importance and significance of the *rates* and of the *phases* at which mineralization occur and, more importantly, they deal with the relationships they found to exist between mineralizable soil nitrogen and the absorption of this nutrient by indicator plants in a controlled culture study.

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*Plant Food Ratios for Sugar Cane Fertilizers:*

Various ratios of N:P:K in a complete fertilizer mixture, which were tested on three different soil types, have given little encouragement that an optimum ratio may be specified. The sugar yields secured were not significantly different even when some rather wide differences in N:P:K ratios were used, and those ratios which were associated with the "best" yields were not in general agreement with the known requirements for the soils studied.

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*Colloids in the Sugar Mill:*

The colloidal impurities present in cane juice are of many different kinds. For each type, a discussion is given as to the sources and properties of the compounds, the changes which take place during the passage of the juice through the sugar mill, and the effects of the substances on the work of the mill.

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*Availability of Insoluble Phosphates:*

An experiment is described in which it was shown that raw rock and reverted phosphates may be equally as available to sugar cane as calcium superphosphate on acid, high phosphate-fixing soils. Raw rock phosphate was found to be more resistant to fixation by the soil than either of the other forms studied.

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*Sixth Congress of International Society of Sugar Cane Technologists:*

A general report on the Louisiana sugar industry and the papers presented at the gathering of delegates are presented by the chairman of the delegation from Hawaii. Both the report to the Experiment Station and the report to the Hawaiian Sugar Technologists were presented by the writer at the annual meetings of the Hawaiian Sugar Planters' Association and the Hawaiian Sugar Technologists in 1938.

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# A Simple Apparatus for the Rapid Determination of Moisture by the Carbide Method*

By EDWARD T. FUKUNAGA and L. A. DEAN†
Hawaii Agricultural Experiment Station

In many agricultural practices it is desirable to have available a simple and rapid method for the determination of moisture. This communication describes a simple apparatus for such a purpose, utilizing the calcium-carbide method.

Calcium carbide reacts with water to form acetylene as indicated below:

$$CaC_2 + 2H_2O \rightarrow HC{\equiv}CH + Ca(OH)_2$$

Thus it follows that 1 gram of water will react with an excess of calcium carbide to produce 690 c.c. of acetylene at 30° C. The principle underlying the carbide method is the direct determination of the moisture of a substance by causing the moisture to undergo such a reaction and measuring the acetylene produced, either by measuring the volume at constant pressure or the pressure at constant volume. The latter procedure apparently permits the simplest and most compact form of apparatus.

## APPARATUS AND MATERIALS

Fig. 1 illustrates the apparatus found suitable for determining moisture by the calcium-carbide method. This consists of a welded cylindrical bomb, 4 inches in diameter and 7 inches in depth, made of an aluminum alloy. A machined flange and plate, held together by bolts and wing nuts, constitute the head of the bomb. The pressure-tight seal between the flange and plate is accomplished by a cork gasket shellacked to the under surface of the plate, and a coating of viscous grease which is smeared on the upper surface of the flange. Into a threaded opening in the plate is fitted a 30-pound pressure gauge with a 4-inch dial. The plate is also equipped with a Weston all-metal thermometer, the stem of which extends into the bomb for a distance of 3½ inches.

The equipment necessary to operate the bomb is:

1. A tin can 4 inches high and of such diameter that it just fits within the bomb.
2. A metal container or vial 1½ inches in diameter and 1½ inches high.
3. Commercial calcium carbide which has been crushed to pass a screen with 0.5 mm. mesh.

## DETERMINATION OF MOISTURE

The above-described apparatus may be used for determining moisture in samples of material containing between 0.5 and 3 grams of water. A sample of the material is weighed into the tin can (item 1 above). The metal cup (item 2), filled

* Contribution of the Department of Chemistry and Soils. Published with the approval of the Director of the Hawaii Agricultural Experiment Station.

† Assistant in Chemistry and Assistant Chemist, respectively.

with calcium carbide and uncovered, is placed in an upright position in the tin can, and the can is inserted into the bomb, which is then sealed. The bomb is held in an inclined position in order to tilt over and discharge the carbide upon the specimen in which moisture is to be determined. The apparatus is then returned to an upright position and shaken with a swirling motion for about a minute. This causes an almost instant reaction between the carbide and the moisture of the sample. It is necessary to shake only until no further increase in pressure is noted. The temperature and pressure are then read and from these data the amount of acetylene generated, which is a measure of the moisture content of the sample, is calculated by applying the gas laws. In general practice, however, it has been found advantageous to construct charts from which the amount of water corresponding to a given pressure can be quickly determined.

The only necessary calibration of the apparatus is an accurate estimation of the volume of the bomb. This may be quite simply ascertained by measuring the increase in pressure caused by a known amount of water.

## Discussion

The above-described procedure was applied to a number of soils, each represented by samples ranging in moisture content from maximum field capacity to below the wilting coefficient. Results were compared with determinations made by the oven-drying method, and a constant difference was found to exist between the two types of measurement. Consequently, the utility of the rapid method as an aid to irrigation control is suggested if the critical soil moisture constants of specific soil types are predetermined on the calcium-carbide basis.

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*Note by Associate Editor.*—A series of independent soil moisture determinations were made by F. Ray Van Brocklin in the chemistry laboratory of the Experiment Station, H.S.P.A., in which the Fukunaga-Dean bomb was compared with conventional oven drying of soil for the purposes of checking the bomb.

While it is recognized that several factors in oven drying of soil detract from the accuracy of this method in arriving at a true moisture value for the specimen it is also recognized that the method itself is one almost universally employed.

It is patent then, we believe, that oven drying should not be considered a criterion of accuracy in the determination of soil moisture.

We found duplicate bomb determinations to be consistent and in most cases to vary from "oven-dry" data by a margin reasonably to be expected as due to differences in the methods used and to errors in manipulation. In all cases the bomb results were lower than oven data, varying from the latter values between 3 per cent and 18 per cent.

One set of comparable data follows:

| Per cent $H_2O$ by bomb | Per cent $H_2O$ by oven at 102° C. |
|---|---|
| 3.74 | 3.86 |
| 5.05 | 6.21 |
| 5.70 | 6.20 |
| 6.80 | 8.14 |
| 7.98 | 9.59 |
| 13.10 | 15.29 |
| 13.90 | 16.31 |
| 18.30 | 19.22 |

F. E. H.

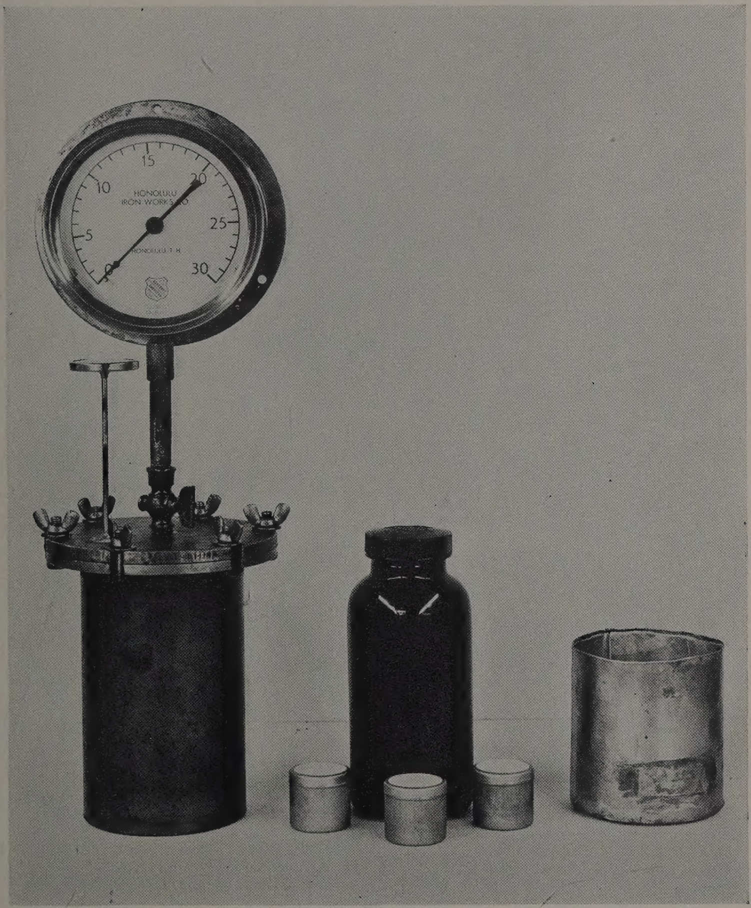



Fig. 1. Apparatus and accessories for determining moisture by the carbide method. (From left to right: bomb, metal vials 1½ inches in diameter by 1½ inches high, powdered calcium carbide, and tin can 4 inches in diameter by 4 inches high.)

# Studies in Experimental Technique

## Selection of Layout: Blocks *versus* Latin Squares

By R. J. Borden

The total amount of variation due to all causes, between the plot yields of a field experiment, can be divided into several relevant portions, and various statistical measures can be used to assess these portions of the total variation to their respective influences. The most generally used measure today is that afforded by Fisher's analysis of variance.

The total sum of the squares of deviations of each plot yield from the mean yield *of all plots* included in the experiment gives a measure of the total amount of variation between the different plots. The sum of the squares of deviations of each plot yield from the mean yield of those *plots with the same treatment* gives a measure of the discrepancies *within* the treatments, which may be due to the position of the plots on the test area, to differences in the interactions of treatment and its position, as well as to the unknown, indeterminable effects upon the various plot yields. The difference between this total sum of squares and the sum squares within the several treatments is the amount of variation between the treatments which has been contributed, and hence is due to the treatments that were given.

Corresponding to these sums of squares (within treatments and between treatments) into which the total sum squares can be divided, we have their mean squares which are calculated by dividing each by its respective number of degrees of freedom. Thereafter the ratio between the mean square for treatment and the mean square for the unknown effect or "error," affords us our test of the significance of the yield differences between the treatments.

As indicated above, the amount of variation *within* the treatments may be due to several causes. When one or more of these can be ascertained and the amount of variation which is contributed thereby can be determined, such an amount can no longer be considered part of the unknown variance or "error" of the experiment which is used in the ratio with the treatment variance for the test of significance. Hence properly designed experiments will be installed in such a way that much of the positional variance and possibly some of the interaction effects can be calculated and used to reduce the unknown or residual error, thus allowing for a more reliable interpretation of the effect of treatment.

We have a good example for this discussion in data taken from the harvesting results of Hamakua Mill Company's Experiment 41 AK, 1938 crop. In this field test, the individual plots were .05 acre in size, with 8 lines per plot. There were 9 replicates of 3 treatments: "G"—No $K_2O$; "H"—175 pounds $K_2O$ per acre; and "I"—350 pounds $K_2O$ per acre. The arrangement of plots*, with plot numbers, treatment identities, and cane yields (tons per acre) are given below; also, the

* This arrangement would be critized by some statisticians because the plots have not been assigned at random.

nine "blocks" and three "squares" as used in the statistical analysis that follows have been indicated:

| Block No. 1 | Block No. 2 | Block No. 3 | Block No. 4 | Block No. 5 | Block No. 6 | Block No. 7 | Block No. 8 | Block No. 9 |
|---|---|---|---|---|---|---|---|---|
| 55 G 53.1 | 56 H 62.6 | 57 I 51.0 | 58 G 43.3 | 59 H 44.0 | 60 I 55.7 | 61 G 38.3 | 62 H 56.8 | 63 I 53.5 |
| 64 H 65.3 | 65 I 63.1 | 66 G 53.9 | 67 H 36.3 | 68 I 45.5 | 69 G 48.5 | 70 H 48.5 | 71 I 49.5 | 72 G 42.9 |
| 73 I 56.6 | 74 G 57.2 | 75 H 50.1 | 76 I 48.9 | 77 G 42.8 | 78 H 43.1 | 79 I 46.9 | 80 G 44.9 | 81 H 47.9 |
| SQUARE NO. 1 | | | SQUARE NO. 2 | | | SQUARE NO. 3 | | |

When these 27 plots have been so arranged that we can calculate that part of the total variation of the experiment which was due to the difference in treatment, and also that part which was due to the position which these 9 blocks of plots occupied on the test area, so that we may get a more reliable estimate of the uncontrolled error of the experiment from which we are to determine the significance of treatment differences, we have the following arrangement of data and their analysis:

| Block no. | Plot nos. "G" | "H" | "I" | Plot yields "G" | "H" | "I" | Block totals |
|---|---|---|---|---|---|---|---|
| 1.......... | 55 | 64 | 73 | 53.1 | 65.3 | 56.6 | 175.0 |
| 2.......... | 74 | 56 | 65 | 57.2 | 62.6 | 63.1 | 182.9 |
| 3.......... | 66 | 75 | 57 | 53.9 | 50.1 | 51.0 | 155.0 |
| 4.......... | 58 | 67 | 76 | 43.3 | 36.3 | 48.9 | 128.5 |
| 5.......... | 77 | 59 | 68 | 42.8 | 44.0 | 45.5 | 132.3 |
| 6.......... | 69 | 78 | 60 | 48.5 | 43.1 | 55.7 | 147.3 |
| 7.......... | 61 | 70 | 79 | 38.3 | 48.5 | 46.9 | 133.7 |
| 8.......... | 80 | 62 | 71 | 44.9 | 56.8 | 49.5 | 151.2 |
| 9.......... | 72 | 81 | 63 | 42.9 | 47.9 | 53.5 | 144.3 |
| Treatment totals ............ | | | | 424.9 | 454.6 | 470.7 | 1350.2 Grand total |
| Averages .................... | | | | 47.2 | 50.5 | 52.3 | |

ANALYSIS OF VARIANCE

| Due to | Sum of squares | Degrees of freedom | Mean variance |
|---|---|---|---|
| Total .................. | 1398.24 | 26 | |
| Treatment ............. | 119.96 | 2 | 59.98 |
| Blocks .................. | 938.29 | 8 | |
| Error .................. | 339.99 | 16 | 21.25 |

$$\text{``F''} = \frac{59.98}{21.25} = 2.82$$

"F" required for minimum significance=3.63.

From this first analysis, we are forced to conclude that such differences between the treatment averages which were secured may quite likely have been the effect of chance; in other words, a definite response to the known treatment differentials which were applied was not reliably proven, for the uncontrolled or error variance

of the experiment was too large in its relation to the treatment variance to warrant any great degree of confidence in the latter.

However, when it is possible to break down the total variation of an experiment more thoroughly than can be done by simply determining the treatment and the block variations, a still further reduction of the error variance is obtained. The triple Latin Square arrangement allows for just such a procedure, for we can secure the amounts of the total variation which has been contributed by the rows of plots and by the columns of plots in the 3 Latin Squares, as well as that contributed by the separate Latin Squares themselves, and also by the interaction of the squares and the treatments.

Using these same data, which fortunately can be studied on the basis of an arrangement of three Latin Squares, we have the following:

| | Plot nos. | Total row yields | Plot nos. | Total column yields | Plot nos. | Total treatment yields "G" | "H" | "I" |
|---|---|---|---|---|---|---|---|---|
| SQUARE NO. 1: | 55,56,57 | 166.7 | 55,64,73 | 175.0 | 55,74,66 | 164.2 | | |
| | 64,65,66 | 182.3 | 56,65,74 | 182.9 | 64,56,75 | | 178.0 | |
| | 73,74,75 | 163.9 | 57,66,75 | 155.0 | 73,65,57 | | | 170.7 |
| Square No. 1 total yield | | 512.9 | | 512.9 | | | | |
| SQUARE NO. 2: | 58,59,60 | 143.0 | 58,67,76 | 128.5 | 58,77,69 | 134.6 | | |
| | 67,68,69 | 130.3 | 59,68,77 | 132.3 | 67,59,78 | | 123.4 | |
| | 76,77,78 | 134.8 | 60,69,78 | 147.3 | 76,68,60 | | | 150.1 |
| Square No. 2 total yield | | 408.1 | | 408.1 | | | | |
| SQUARE NO. 3: | 61,62,63 | 148.6 | 61,70,79 | 133.7 | 61,80,72 | 126.1 | | |
| | 70,71,72 | 140.9 | 62,71,80 | 151.2 | 70,62,81 | | 153.2 | |
| | 79,80,81 | 139.7 | 63,72,81 | 144.3 | 79,71,63 | | | 149.9 |
| Square No. 3 total yield | | 429.2 | | 429.2 | | | | |

Grand total treatments: G=424.9; H=454.6; I=470.7.

Our analysis of variance now becomes the following:

| Due to | Sum of squares | Degrees of freedom | Mean variance |
|---|---|---|---|
| Total | 1398.24 | 26 | |
| Treatments | 119.96 | 2 | 59.98 |
| Rows (137.87+65.87+51.80)= | 255.54 | (2+2+2)=6 | |
| Columns (65.53+27.64+15.55)= | 108.72 | (2+2+2)=6 | |
| Squares | 682.74 | 2 | |
| Interaction=[980.11—(119.96+682.74)] (Treatments and Squares) | 177.41 | [8–(2+2)] 4 | |
| Error | 53.87 | 6 | 8.98 |

$$\text{"F"} = \frac{59.98}{8.98} = 6.68 \qquad \text{"F" required} = 5.14$$

$$\text{SEd} = \sqrt{\frac{8.98}{9}} \times 2 = 1.41$$

From this analysis it will be seen that the total and the treatment sums of squares check with the previous analysis (1398.24 and 119.96 respectively) as they should

do, but that the corresponding figure for positional factors (blocks) which was 938.29 has now been increased to a total of 1224.41 (255.54 + 108.72 + 682.74 + 177.41), and that this has brought about a considerable reduction in the sum of squares due to error—from 339.99 to 53.87.

This second analysis of the total variation of the experiment has made it possible to determine the effect contributed by the positional variance with more refinement than was possible with determinations of the block variance alone; it has likewise enabled the effect of the interaction between treatment and position on the test area to be measured. Such measurable effects are legitimately deducted from the total variance, thus reducing the unknown effect or error variance, upon which the true estimate of significance is based.

Here, then, we find our original conclusion may be changed. The error variance now appears sufficiently small in relation to the treatment variance to justify our conclusion that the yield differences obtained are not likely the effect of chance, and hence are probably the effect of the known treatment (potash) differentials which were applied.

Thus the value of laying out field experiments so that their results may be studied by modern refinements of statistical methods is exemplified: without this multiple Latin Square arrangement there could have been considerable doubt that the observed yield differences were due to applications of potash; with this Latin Square arrangement and our subsequent analysis, we can feel more confident that potash was actually responsible for the yield increases that were obtained.

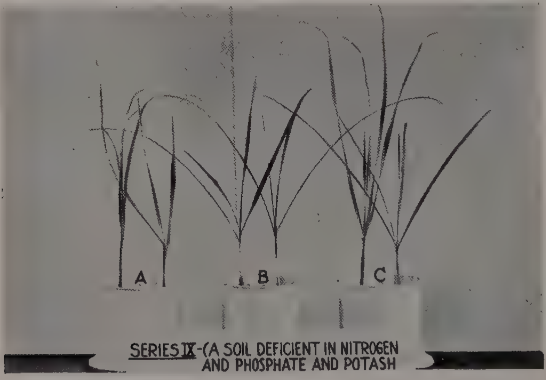
# A Pictorial Showing the Effects of Delayed Weed Control Upon Subsequent Growth of Sugar Cane

By R. J. Borden


*A*—Cane growth at 8 weeks; no weeds allowed to grow.
*B*—Cane growth at 8 weeks; weeded at 6 weeks.
*C*—Cane and weed growth at 8 weeks.

*NOTE.*—In all instances when pots were weeded, all weed growth was crushed and returned to the surface of the soil in the pot in which it grew. Nearly complete decomposition of this material had taken place when the cane was 4 months old; hence the plant food which had been taken up by the weeds had *presumably* been returned to the soil, and logically it should have been made available for subsequent cane growth. The probable fallacy of this presumption is indicated in the pictures which follow which were taken when the plants were 7 months old. It appears quite certain that the growth which has been lost by this crop will not be made up.


*A*—No weeds allowed to grow. *B*—Weeded at 6 weeks. *C*—Weeded at 8 weeks.

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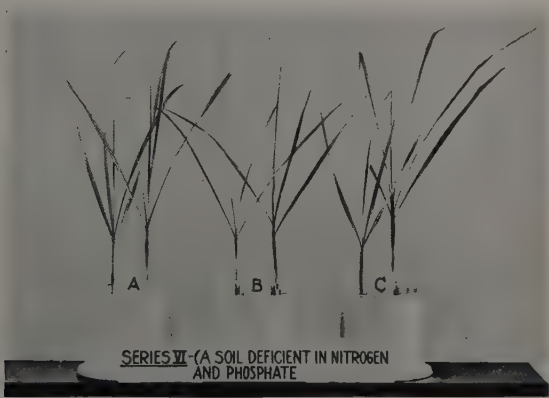


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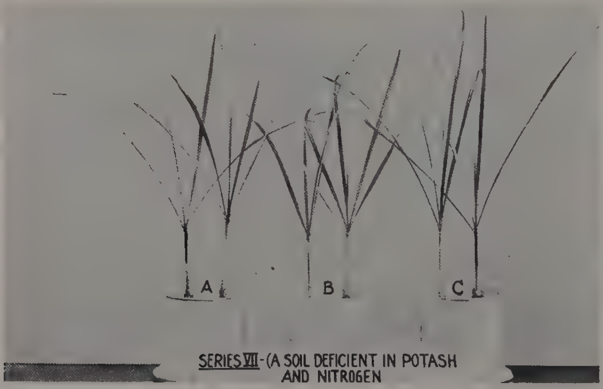


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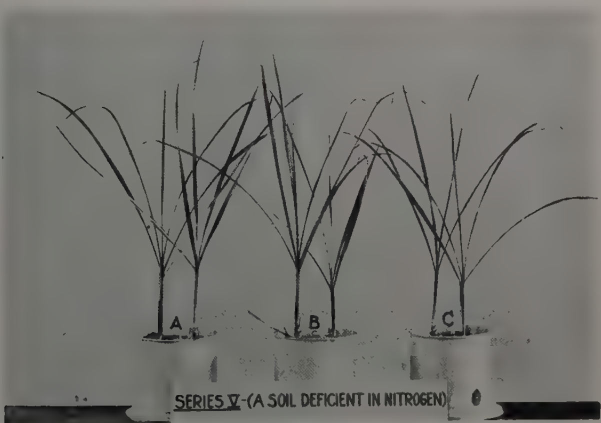

# Mineralizable Nitrogen in Some Hawaiian Soils*

By Edward T. Fukunaga and L. A. Dean†
Hawaii Agricultural Experiment Station

With the increasing interest in the relation between utilization of nitrogen and growth and development of economic plants in Hawaii, attention has apparently been centered upon the maintenance of suitable levels of nitrogen in the plant with little regard for the natural nitrogen-supplying ability of the soil in which the plants are grown. In general, considerably over 90 per cent of the soil nitrogen exists in organic compounds of such a nature that this element cannot be utilized by green plants. However, certain microbiological activities within soils bring about the decomposition of these compounds with the liberation of mineral forms of nitrogen (i.e., nitrate and ammonia compounds) which are readily utilized by economic plants.

Attempts have often been made to use the nitrate and ammonia contents of soils as measures of the nitrogen fertility of soils, but with indifferent success. True, such a method measures the available nitrogen at the time the samples are taken, but gives little information as to possible future release of available nitrogen as a result of microbiological activities. Further, the data accruing from determinations of nitrate and ammonia may be seriously obscured because of the influences exerted by such factors as irrigation, rainfall, soil management practices prior to sampling, and duration and conditions of storage of soil specimens before the analyses are made. The purpose of this investigation was to adapt some procedure for measuring not only the existing available nitrogen in soils but also that which is released as a result of soil biological activities during the period a crop is being grown.

## Definitions

Since there appears in the literature considerable confusion regarding the definitions and terminology applied to the changes brought about in the soil nitrogen compounds by microbiological activities, the following definitions are offered to facilitate discussion:

*Mineralization:* The decomposition of the organic compounds of nitrogen into ammonium salts and nitrates.

*Ammonification:* The decomposition of the organic compounds of nitrogen into ammonium salts. (This is one of the steps taking place in mineralization.)

*Nitrification:* The oxidation of ammonium salts to nitrites to nitrates.

*Denitrification:* The reduction of nitrates to ammonium salts or to gaseous nitrogen.

*Mineralizable Nitrogen:* In this paper the term mineralizable nitrogen is used

* Contribution of the Department of Chemistry and Soils. Published with the approval of the Director of the Hawaii Agricultural Experiment Station.

† Assistant in Chemistry and Assistant Chemist, respectively.

to denote the amount of organic nitrogen which is mineralized when a soil is incubated under standard optimum conditions in the laboratory.

## Historical

During the first quarter of this century numerous workers studied the microbiological activities of soils as a means of measuring their fertility. Apparently the majority of these studies were concerned with the mineralization of nitrogenous materials added to soils rather than the mineralization of the naturally occurring nitrogenous compounds. However, studies on nitrate accumulation, such as reported by Russell (5), give some indication as to the rate of mineralization of the nitrogen within the soils. Waksman (6) studied the "nitrification of the soils' own nitrogen" in the laboratory by incubating soils wetted to optimum moisture conditions for 30 days. The increase in nitrates caused by this treatment was found to indicate the forms of nitrogen present in a particular soil and the speed with which they were transformed into nitrates and thus made available to plants. However, in this study there was no consideration of the changes occurring in the ammonia contents of the soils. Richardson (3), Orchard (2), and others working at the Rothamsted Experimental Station (4) have measured the increase in the nitrate and ammonia contents of soils resulting from incubation under ideal conditions in the laboratory. This mineralizable nitrogen content of soils was found to be related to the nitrogen responses in field experiments and to the nitrogen content of the non-leguminous herbage of pastures.

## Methods

The laboratory determination of the amount of mineralizable nitrogen of a given soil consists essentially in wetting the soil to optimum moisture content, incubating it under standard conditions, and determining the amounts of ammonia and nitrate nitrogen*.

Since no information was available, a test was undertaken to determine the optimum moisture content of a soil for mineralization. Samples of one soil, maintained at different moisture contents, were incubated under standard conditions and the mineralizable nitrogen determined.

| Percentage of moisture | Mineralizable nitrogen mg/100g. |
|---|---|
| 38 | 7.8 |
| 48 | 13.1 |
| 58 | 13.4 |
| 64* | 13.3 |
| 78 | 12.8 |
| 88 | 5.8 |

* Moisture equivalent.

The optimum moisture content for mineralization appears, as indicated, to be similar to the range suitable for the growth of green plants. Since the moisture equivalent of a soil is relatively easy to ascertain, it was chosen as the standard point to which all samples were moistened before mineralization determinations.

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* The essential features of the technique for determining mineralizable nitrogen were not originated by the authors; they were obtained from the workers in the Chemistry Department of the Rothamsted Experimental Station.

*Preparation of Sample for Incubation:* In order for a sample of soil to be moistened to its moisture equivalent, it is necessary to determine both the moisture content and the moisture equivalent. The suction method suggested by Bouyoucos (1) has proved to be rapid and satisfactory for this purpose. The method consists in pouring a properly prepared soil sample into a 5-cm. Buchner funnel to a depth of 2.5 cm. The funnel is then placed in a beaker and water added until it almost reaches the level of the soil. After 24 hours the funnel is placed in a suction flask and suction continued for 15 minutes after the excess water has been drawn off. The moisture content of this soil is considered to be the moisture equivalent.

The weight of soil "y" necessary in order to have 50 grams of oven-dry soil may be calculated from the following:

$$y = 50(1 + p/100)$$

where "p" is the percentage of moisture in the sample on the dry basis. The amount of water "W" which must be added to "y" grams of soil in order to bring the soil to the moisture equivalent "M" may be calculated from

$$W = \frac{M - P}{2}$$

It has been recommended by other workers that, when the soils are incubated, the addition of certain mineral salts may facilitate microbiological activities. Consequently, the procedure adopted called for adding 10 c.c. of 0.25 per cent solution of di-potassium phosphate as part of the liquid used for wetting the soils to the moisture equivalent.

The calculated amount of soil "y" is weighed out and placed on a square of glazed paper, 10 c.c. of nutrient solution added, and the soil thoroughly mixed by rubbing with the fingers. Then the additional water required (W-10) is added by means of a burette or Mohr pipette, the soil is again rubbed, and transferred to a 500-c.c. Erlenmeyer flask. A test tube containing 15 c.c. of 30 per cent potassium hydroxide is placed in the flask in an upright position, and the flask is tightly stoppered. The flask is incubated for 3 weeks at 30° C. It is advisable, during the period of incubation, to change the atmosphere in the flask every 3 days by blowing air into the mouth of the container.

*Estimation of Ammonia and Nitrate Nitrogen:*

After the period of incubation the soil is removed from the flask and the nitrate and ammonia nitrogen contents are determined. Any reliable method for the estimation of these soil constituents may be used.

*Estimation of Carbon Dioxide Evolved:*

If desired, the carbon dioxide evolved by the soil microorganisms during the period of incubation may easily be determined by the method of Orchard (2). The contents of the potassium-hydroxide-containing test tube are washed into a titration flask and the solution is neutralized, using approximate 2N hydrochloric acid until the color of phenolphthalein just disappears. The bicarbonates are then titrated using standard N/10 hydrochloric acid and either methyl orange or brom phenol blue as an indicator. It is advisable to incubate a blank if this determination is to be made.

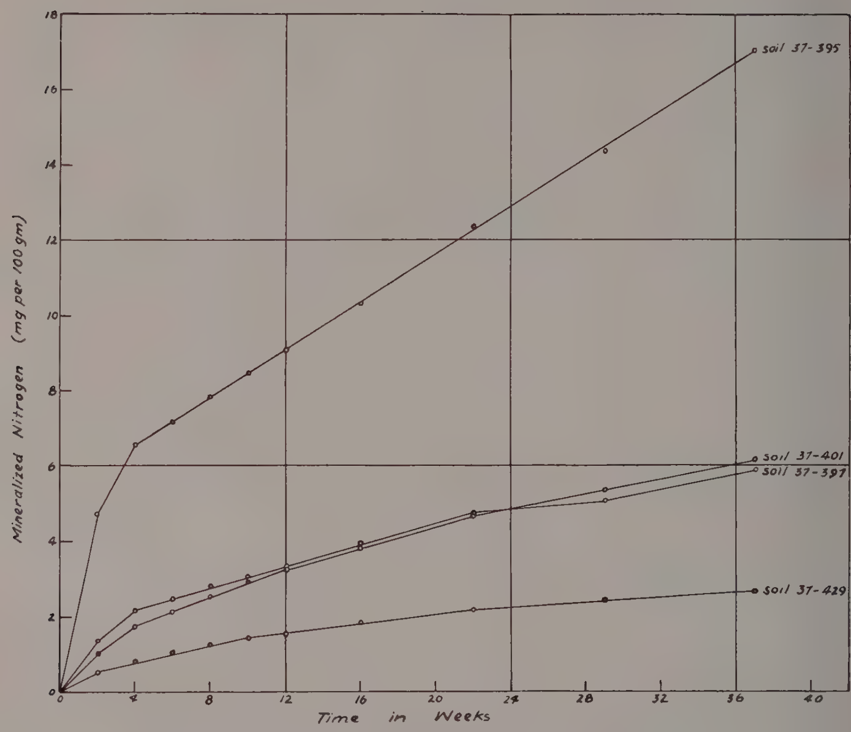


Fig. 1. The rate of mineralization of the nitrogen within soils.

## The Rate of Mineralization of Nitrogen Within the Soil

In Hawaii, many economic crops are grown on the same soil for long periods of time without disturbing the natural soil processes. Consequently, it is of interest to know something of the changes that take place in the rate of mineralization of the nitrogen within the soil when a sample is incubated over a long period of time.

Triplicate samples of four soils were incubated according to the previously described procedure. At intervals these soils were transferred into Buchner funnels and leached with 500 c.c. of water. The soils were then treated with 10 c.c. of nutrient solution and suction applied for 15 minutes after the solution had drained through them. The soils were replaced in their original flasks for further incubation. The combined ammonia and nitrate nitrogen in the leachates was determined. The results of these determinations for various intervals over a period of 37 weeks are presented in Fig. 1. These data suggest that the mineralization proceeds in two distinct phases; namely, an initial phase of rapid release of nitrogen taking place during the first 3 to 4 weeks of incubation, and a second phase having a much slower rate of release of nitrogen. The rate of release during the second phase of mineralization of three of the soils apparently decreases with time.

The ratios of carbon evolved as $CO_2$ to nitrogen released as ammonium salts and nitrates during the various intervals of incubation were calculated, and are presented in Table I. These data show that during the first two intervals of incuba-

tion there was a much lower C/N ratio than during the remainder of the period. This suggests that during the initial rapid mineralization phase the microbiological activities of the soil are predominantly associated with nitrogenous compounds.

TABLE I

THE C/N RATIO OF THE C RELEASED AS CARBON DIOXIDE AND N RELEASED AS NITRATES AND AMMONIUM SALTS AT VARIOUS INTERVALS DURING A 37-WEEK PERIOD OF INCUBATION

| | C/N ratio | | | |
|---|---|---|---|---|
| Time in weeks | Soil 37–395 | Soil 37–397 | Soil 37–401 | Soil 37–429 |
| 0–2 | 14.4 | 14.4 | 13.0 | 27.6 |
| 2–4 | 15.8 | 11.2 | 16.4 | 35.8 |
| 4–6 | 44.8 | 28.0 | 33.4 | 35.0 |
| 6–8 | 37.0 | 22.4 | 32.2 | 34.8 |
| 8–10 | 35.8 | 21.6 | 30.6 | 29.2 |
| 10–12 | 37.0 | 24.2 | 41.8 | 50.0 |
| 12–16 | 41.0 | 26.6 | 37.2 | 40.8 |
| 16–22 | 32.4 | 21.0 | 34.0 | 32.0 |
| 22–29 | 39.6 | 28.8 | 46.8 | 55.6 |
| 29–37 | 36.2 | 24.6 | 36.4 | 52.8 |

## Mineralizable Nitrogen in Relation to the Uptake of Nitrogen by Panicum Grass

A series of soils was collected from various parts of the Territory for the purpose of comparing the total amount of nitrogen taken up by plants with mineralizable nitrogen contents of the soils. Duplicate 4-kilogram samples of each soil were potted, fertilized with 2 gm. of $K_2HPO_4$ per pot, and 15 cuttings of panicum grass *(Panicum purpurascens)* planted. The grass, after growing in these pots for 78 days, was harvested, and the total nitrogen in the combined roots and tops determined. The scatter diagram, Fig. 2, shows the relationship between the mineralizable nitrogen in 4 kilograms of soil and the amount of nitrogen existing in the panicum grass which had been grown on the soil. A statistical analysis of the data showed a highly significant relationship to exist. It was found that the average utilization of the mineralizable nitrogen by the grass during the period of growth was 64 per cent.

## Summary

This paper deals with a study of mineralizable nitrogen in a number of Hawaiian soils, consideration being given to: (1) definitions, (2) determination of mineralizable nitrogen, (3) rate of mineralization, and (4) the relation between the mineralizable nitrogen and uptake of nitrogen by panicum grass; and may be summarized as follows:

*(a)* The moisture equivalent was shown to be a satisfactory moisture content at which to maintain soils when they are incubated for the purpose of determining mineralizable nitrogen.

*(b)* There appear to be two phases of nitrogen release when soils are incubated —an initial rapid phase (3 to 4 weeks), followed by a phase of slow release.

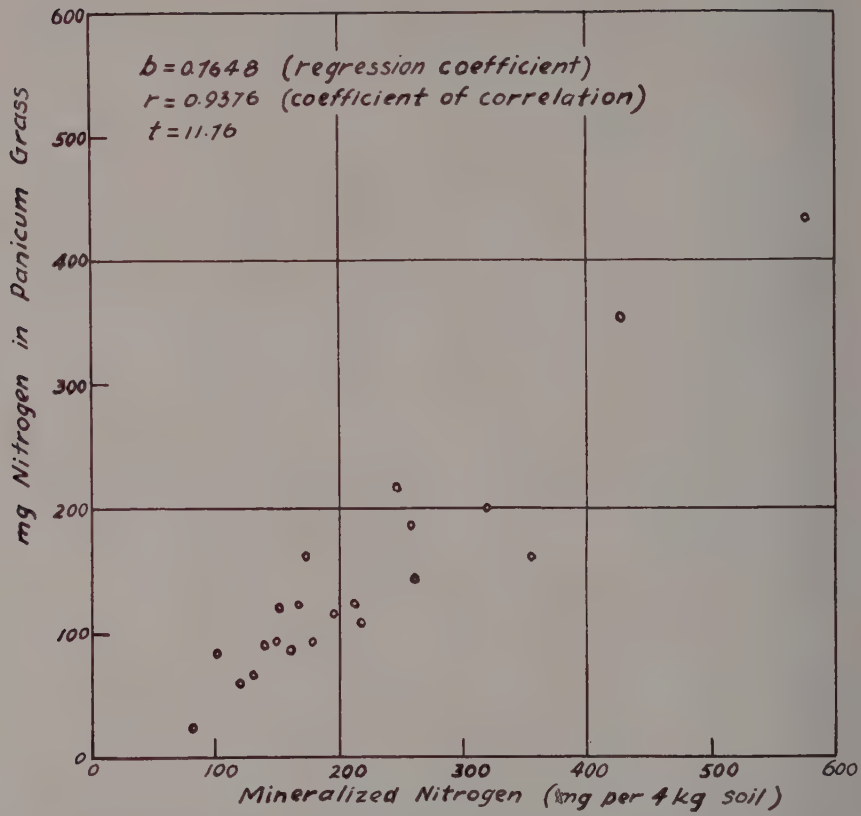


Fig. 2. Scatter diagram showing the relation between the uptake of nitrogen by panicum grass grown in pots to the mineralizable nitrogen of the soil.

*(c)* The initial phase appears to be associated with the microbiological decomposition of predominately nitrogenous compounds.

*(d)* A very significant relationship was found between the mineralizable nitrogen and the uptake of nitrogen by panicum grass grown in pots.

## Literature Cited

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# Plant Food Ratios for Sugar Cane Fertilizers

By R. J. Borden

Several years ago, when studying the tables of analytical data compiled by W. W. G. Moir* from work previously reported by Stewart†, and Wolters‡, we were struck with the rather remarkable similarity of the ratio of $N:P_2O_5:K_2O$ which was indicated by the chemical analyses of the H 109 sugar cane plants, not only when they had been harvested at different stages of their growth but also when they were taken from plots which had received different fertilizer treatments. For instance, when the percentage figures for nitrogen, phosphoric acid, and potash, which were found in the total dry weights from each individual harvest are set up in their approximate N:P:K ratio, we have evidence that such a ratio did not deviate very widely from 30:10:60 (3:1:6) in spite of the age of the cane or the plant food which it had received. Two tables which follow, summarize this evidence. (When the data in these two tables are compared, it must be remembered that the roots were included in the data of Table I but not in Table II):

TABLE I

(Data from analyses of crop from Oahu Sugar Company, Field 40, include total N, $P_2O_5$, and $K_2O$ in total dry matter: tops, stalks, trash and roots.)

Approximate ratios of $N:P_2O_5:K_2O$

| Fertilizer treatment | At 1½ mos. | At 3½ mos. | At 5 mos. | At 8 mos. | At 12 mos. | At 17 mos. | At 24 mos. | Avg. for treatment |
|---|---|---|---|---|---|---|---|---|
| N | 29:11:60 | 35:9:56 | 29:7:63 | 26:13:60 | 27:8:64 | 27:10:62 | 31:8:60 | 29:9:62 |
| NP | 27:13:59 | 33:8:58 | 29:7:63 | 27:14:58 | 30:10:59 | 28:10:61 | 28:8:63 | 29:10:60 |
| NK | 30:11:58 | 33:9:58 | 27:7:65 | 26:13:60 | 25:9:66 | 25:9:65 | 32:7:60 | 28:9:62 |
| NPK | 30:12:57 | 32:9:58 | 26:7:66 | 25:13:61 | 26:9:65 | 25:9:65 | 28:7:64 | 28:9:62 |
| Average for age: | 29:12:58 | 33:9:58 | 28:7:64 | 26:13:60 | 27:9:63 | 26:10:63 | 30:8:62 | |

Grand average—29:10:61

TABLE II

(Data from analyses of crop from Pioneer Mill Company, Field 30, include percentages of N, $P_2O_5$, and $K_2O$ from stalks, leaves, and tops only, i.e., *no roots included.*)

Approximate ratios of $N:P_2O_5:K_2O$

| Fertilizer treatment | At 6 mos. | At 12 mos. | At 15 mos. | At 21 mos. | Avg. for treatment |
|---|---|---|---|---|---|
| N ............. | 32:6:62 | 28:6:66 | 28:8:64 | 24:7:69 | 28:7:65 |
| NP ........... | 27:9:64 | 24:9:67 | 27:9:64 | 21:9:70 | 25:9:66 |
| NK ........... | 32:6:62 | 27:6:67 | 26:7:67 | 23:6:71 | 27:6:67 |
| NPK .......... | 23:8:69 | 23:9:68 | 26:9:65 | 21:9:70 | 23:9:68 |
| Average for age | 29:7:64 | 26:7:67 | 27:8:65 | 22:8:70 | |

Grand average — 26:8:66

* Reports of Association of Hawaiian Sugar Technologists, pp. 189–192, 1930.

† Reports of Association of Hawaiian Sugar Technologists, pp. 199–220, 1929.

‡ Reports of Association of Hawaiian Sugar Technologists, pp. 141–159, 1929.

*Detail of Present Study*:*

Discussions, pro and con, of the probable value of an optimum ratio of the three principal plant foods for a complete fertilizer mixture have been common; specific evidence for such discussions has, however, been lacking. Difficulties are immediately apparent as soon as one undertakes to make a plan to secure this evidence, since with changes for the desired ratios, there will be changes in the total amounts of each nutrient supplied, and this factor itself may be largely responsible for the results which are secured.

In this attempt to secure comparable evidence, however, we planned a carefully controlled pot test, using three quite different soils which were potted, planted to POJ 2878 cane, and fertilized adequately with specific N:P:K ratios in triplicate. Since this was to be a study of N:P:K ratios, adequate amounts (particularly of nitrogen) for a normal crop were allowed for even the lowest figures of these ratios. The crop was harvested at the age of 12 months and the data which were secured have been summarized in the tables which follow.

*The Manoa Soil:*

The soil from Manoa was a residual, yellowish-brown silty loam, acid in its reaction (pH 5.6) and with a granular structure that makes it porous and well drained. It is known to be deficient in all three of the principal plant foods as well as in calcium. It has a very strong capacity to fix applied phosphates.

*The Makiki Soil:*

The alluvial soil from Makiki was a chocolate-brown loam, neutral in reaction (pH 7.2), with a much finer structure than the Manoa soil, and which drains more slowly when irrigated and tends to pack quite firmly, without cracking, however, as it dries. It is known to be well supplied with available phosphates and potash but is deficient in nitrogen.

*The Yamada Soil:*

The Yamada soil came from a field of brown-black clay loam alluvium which drains very slowly and cracks badly as it dries out. It has a neutral reaction (pH 6.9), an ample amount of both phosphate and potash but is deficient in its nitrogen supply.

*The N:P:K Ratios:*

Since it was physically impossible to include all of the suggested N:P:K ratios which we would have liked to test, we selected for certain groups which would enable us to study the effects of a change in the ratio of any two of these plant foods while the other nutrient was held at a constant. Our selection also afforded a chance to study the effect of a variation in one nutrient when the ratio of the other two was unchanged. We also included the 3:1:6 (1:⅓:2) ratio which was suggested by the results shown in Tables I and II. Hence we have results which can be compared in the following groups:

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* Experiment Station, H.S.P.A. Project A-105-No. 97.

| Group I | Group II | Group III |
|---|---|---|
| Nitrogen constant | Phosphate constant | Potash constant |
| $N:P_2O_5:K_2O$ ratios | $N:P_2O_5:K_2O$ ratios | $N:P_2O_5:K_2O$ ratios |
| 1:0:4 | 1:1:3 | 1:3:1 |
| 1:1:3 | 2:1:2 | 2:2:1 |
| 1:2:2 | 3:1:1 | 3:1:1 |
| 1:3:1 | | |
| 1:4:0 | | |

| Group IV | Group IVa | Group V | Group VI |
|---|---|---|---|
| N and K constant | N and K constant | N and P constant | P and K constant |
| $N:P_2O_5:K_2O$ ratio | $N:P_2O_5:K_2O$ ratio | $N:P_2O_5:K_2O$ ratio | $N:P_2O_5:K_2O$ ratio |
| 1:3:1 | 1:2:2 | 1:1:3 | 3:1:1 |
| 1:½:1 | 1:⅓:2 | 1:1:½ | ½:1:1 |

The pots were fertilized with their respective ratios of N:P:K from ammonium sulphate, superphosphate, and muriate of potash, once a month for the first eight consecutive months only. The total amounts used varied with the ratio to be provided, but unless a nutrient were to be omitted altogether, it was furnished for the lowest figure of a ratio, at an amount believed to be sufficient to grow normal cane; hence there was undoubtedly some luxury consumption when the higher amounts of a ratio were supplied.

*Discussion:*

The results are first presented and discussed separately for each of the three soils, and later the more pertinent comparisons from similar ratios on the different soils are summarized.

TABLE III

THE MANOA SOIL

(Figures are averages of three pots.)

| Group | N:P:K ratio | lb cane | Y%C | lb sugar | Crusher juice analyses % Glucose | % N | % $P_2O_5$ | % $K_2O$ | No. of stalks per pot | Wgt. per ft. of stalk (lb) | % of total stalks tasseled |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 1:0:4 | 3.3 | 11.0 | .36 | .52 | .36 | .007 | .27 | 6 | .26 | 0.6 |
| | 1:1:3 | 17.4 | 15.1 | 2.64 | .45 | .05 | .03 | .21 | 11 | .41 | 16 |
| | 1:2:2 | 18.2 | 15.2 | 2.76 | .48 | .05 | .06 | .13 | 11 | .39 | 12 |
| | 1:3:1 | 17.5 | 15.1 | 2.64 | .66 | .04 | .09 | .07 | 11 | .39 | 0 |
| | 1:4:0 | 7.8 | 11.1 | .87 | .84 | .13 | .12 | .03 | 7 | .28 | 21 |
| II | 1:1:3 | 17.4 | 15.1 | 2.64 | .45 | .05 | .03 | .21 | 11 | .41 | 16 |
| | 2:1:2 | 20.6 | 13.0 | 2.62 | .57 | .10 | .02 | .09 | 12 | .41 | 13 |
| | 3:1:1 | 16.3 | 14.3* | 2.33 | .76 | .19 | .02 | .07 | 13 | .33 | 0 |
| III | 1:3:1 | 17.5 | 15.1 | 2.64 | .66 | .04 | .09 | .07 | 11 | .39 | 0 |
| | 2:2:1 | 18.3 | 14.3 | 2.60 | .63 | .08 | .05 | .06 | 13 | .36 | 0 |
| | 3:1:1 | 16.3 | 14.3 | 2.33 | .76 | .19 | .02 | .07 | 13 | .33 | 0 |
| IV | 1:3:1 | 17.5 | 15.1 | 2.64 | .66 | .04 | .09 | .07 | 11 | .39 | 0 |
| | 1:½:1 | 20.6 | 13.0 | 2.62 | .57 | .10 | .02 | .09 | 12 | .41 | 13 |
| IVa | 1:2:2 | 18.2 | 15.2 | 2.76 | .48 | .05 | .06 | .13 | 11 | .39 | 12 |
| | 1:⅓:2 | 17.7 | 15.1 | 2.67 | .50 | .12 | .007 | .25 | 10 | .42 | 7 |
| V | 1:1:3 | 17.4 | 15.1 | 2.64 | .45 | .05 | .03 | .21 | 11 | .41 | 16 |
| | 1:1:½ | 18.3 | 14.3 | 2.60 | .63 | .08 | .05 | .06 | 13 | .36 | 0 |
| VI | 3:1:1 | 16.3 | 14.3 | 2.33 | .76 | .19 | .02 | .07 | 13 | .33 | 0 |
| | ½:1:1 | 18.2 | 15.2 | 2.76 | .48 | .05 | .06 | .13 | 11 | .39 | 12 |
| Amount of difference needed for significance: | | 2.1 | 1.3 | .8 | | | | | | | |

* Only one juice sample, others lost.

*The Manoa Soil:*

When N is held at a constant (Group I) and the ratio of P to K is altered, we find no effect upon the cane yield or its quality, except when P or K is omitted entirely, in which case both yield and quality are adversely influenced. (It must be remembered that this soil is known to be deficient in phosphate and potash.) The percentage of P and K in the crusher juice was influenced directly and in accordance with the change in the P:K ratio.

With P held constant (Group II), the change of a 2 to 2 N:K ratio to either a 1 to 3 or to a 3 to 1 ratio caused a decrease in the cane yield which, however, had a better quality and hence gave no reliable differences in the sugar yield. Glucose and nitrogen in the crusher juice were increased with the higher nitrogen ratio, while potash also followed its change in the fertilizer ratio; phosphate was not affected. Cane weight per foot of stalk was somewhat less with the lowered potash ratio.

No reliable effect on yields or quality is noted from changing the N:P ratio when the K is held constant (Group III). Both nitrogen and phosphate in the crusher juice follow their changes in the fertilizer ratio, but glucose is not as definitely affected as it appeared to be with the higher nitrogen in the N:K ratios. There is an indication that the lower phosphate ratio has produced a somewhat lighter stalk weight.

With a 1:1 ratio of N and K (Group IV) a higher ratio of P to N and K (as 1:3:1) gave less cane, a better quality, and a similar sugar yield as a lower ratio (1:½:1). With a 1:2 ratio of N to K (Group IVa) there was no effect when a change in the ratio of P to N and K was made. Altering the N:P:K ratio from 1:1:3 to 1:1:½ (Group V) had no measurable effect. There was no significant amount of difference produced by changing the 3:1:1 ratio to ½:1:1 (Group VI). In these comparisons also, crusher juice analyses show positive relationships with the respective nutrient ratios that were supplied.

TABLE IV
THE MAKIKI SOIL

| Group | N:P:K ratio | lb cane | Y%C | lb sugar | Crusher juice analyses % Glucose | % N | % $P_2O_5$ | % $K_2O$ | No. of stalks per pot | Wgt. per ft. of stalk (lb) | % of total stalks tasseled |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 1:0:4 | 16.1 | 15.4 | 2.48 | .77 | .04 | .05 | .25 | 16 | .36 | 12 |
| | 1:1:3 | 16.8 | 14.5 | 2.42 | .51 | .05 | .08 | .23 | 10 | .41 | 21 |
| | 1:2:2 | 15.6 | 14.5 | 2.23 | .60 | .03 | .10 | .23 | 12 | .39 | 26 |
| | 1:3:1 | 13.4 | 14.8 | 1.99 | .54 | .03 | .10 | .18 | 10 | .37 | 0 |
| | 1:4:0 | 12.9 | 15.2 | 1.93 | .59 | .04 | .12 | .05 | 12 | .35 | 11 |
| II | 1:1:3 | 16.8 | 14.5 | 2.42 | .51 | .05 | .08 | .23 | 10 | .41 | 21 |
| | 2:1:2 | 15.0 | 13.7 | 2.06 | .53 | .07 | .08 | .15 | 12 | .34 | 0.4 |
| | 3:1:1 | 16.8 | 13.7 | 2.27 | .89 | .13 | .09 | .10 | 16 | .36 | 0 |
| III | 1:3:1 | 13.4 | 14.8 | 1.99 | .54 | .03 | .10 | .18 | 10 | .37 | 0 |
| | 2:2:1 | 13.0 | 13.8 | 1.79 | .74 | .10 | .12 | .11 | 11 | .38 | 0.5 |
| | 3:1:1 | 16.8 | 13.7 | 2.27 | .89 | .13 | .09 | .10 | 16 | .36 | 0 |
| IV | 1:3:1 | 13.4 | 14.8 | 1.99 | .54 | .03 | .10 | .18 | 10 | .37 | 0 |
| | 1:½:1 | 15.0 | 13.7 | 2.06 | .53 | .07 | .08 | .15 | 12 | .34 | 0.4 |
| IVa | 1:2:2 | 15.6 | 14.5 | 2.23 | .60 | .03 | .10 | .23 | 12 | .39 | 26 |
| | 1:⅓:2 | 18.6 | 14.1 | 2.63 | .54 | .05 | .06 | .26 | 17 | .40 | 12 |
| V | 1:1:3 | 16.8 | 14.5 | 2.42 | .51 | .05 | .08 | .23 | 10 | .41 | 21 |
| | 1:1:½ | 13.0 | 13.8 | 1.79 | .74 | .10 | .12 | .11 | 11 | .38 | 0.5 |
| VI | 3:1:1 | 16.8 | 13.7 | 2.27 | .89 | .13 | .09 | .10 | 16 | .36 | 0 |
| | ½:1:1 | 15.6 | 14.5 | 2.23 | .60 | .03 | .10 | .23 | 12 | .39 | 26 |
| Amount of difference needed for significance: | | 4.7 | .7 | .64 | | | | | | | |

*The Makiki Soil:*

The somewhat higher experimental error which was associated with the cane yields from this soil make it rather difficult to draw definite conclusions. However, certain trends may be indicated and we should not overlook them in this discussion.

With N constant (Group I) a departure from a 2 to 2 ratio of P to K, which increases the P or decreases the K, appears to decrease the cane yield but to have no effect on cane quality. With N and P equal and constant (Group V), a low ratio of K to N and P has apparently given a poorer cane quality and lower sugar yields. With N and K equal and constant (Group IV) the quality *is* adversely affected with the lower ratio of P to the N and K, but with a 1:2 ratio of N:K as a constant (Group IVa) no such effect on cane quality is found. Thus we have the following effects on cane quality which may be concerned with our fertilizer ratios: With N:P:K ratios as (a) 1:1:3, 1:2:2, or 1:3:1, we find no difference in their effect on cane quality; (b) a change from a 1:1:3 to 1:1:½ ratio gives us a poorer quality; (c) a 1:½:1 ratio gives a significantly poorer figure than a 1:3:1 ratio; and (d) the small difference in quality between a 1:2:2 and a 1:⅓:2 ratio is not significant.

No proven effect upon the cane yield was found from changing either the N:K or the N:P ratios, but both of these changes apparently had an effect on the quality. With P constant (Group II), the quality was better with a higher ratio of K to N; with K constant (Group III) the quality was better with the higher ratio of P to N. But it is believed that both of these apparent improvements are probably the result of the better quality associated with the smaller total amounts of nitrogen rather than the effects of the higher K:N and P:N ratios, for the ½:1:1 ratio (Group VI) gave a better cane quality than the 3:1:1.

Although not as consistent as on the Manoa soil, the crusher juice analyses do show percentages of N, $P_2O_5$, and $K_2O$ that line up favorably with the amounts supplied in the different fertilizer ratios. Similarly, the higher glucose figures are associated with the higher nitrogen ratios.

TABLE V

THE YAMADA SOIL

| Group | N:P:K ratio | lb cane | Y%C | lb sugar | Crusher juice analyses % Glucose | % N | % $P_2O_5$ | % $K_2O$ | No. of stalks per pot | Wgt. per ft. of stalk (lb) | % of total stalks tasseled |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 1:0:4 | 12.1 | 13.4 | 1.61 | .46 | .07 | .01 | .31 | 9 | .35 | 40 |
| | 1:1:3 | 14.9 | 14.8 | 2.08 | .63 | .06 | .06 | .25 | 10 | .40 | 24 |
| | 1:2:2 | 17.9 | 15.9 | 2.85 | .54 | .04 | .10 | .16 | 12 | .39 | 25 |
| | 1:3:1 | 18.0 | 15.4 | 2.77 | .52 | .03 | .13 | .09 | 10 | .38 | 22 |
| | 1:4:0 | 13.2 | 14.5 | 1.68 | .68 | .05 | .14 | .04 | 7 | .37 | 31 |
| II | 1:1:3 | 14.9 | 14.8 | 2.08 | .63 | .06 | .06 | .25 | 10 | .40 | 24 |
| | 2:1:2 | 18.4 | 14.4 | 2.63 | .76 | .13 | .06 | .13 | 14 | .37 | 12 |
| | 3:1:1 | 13.5 | 13.0 | 1.75 | .81 | .21 | .03 | .07 | 15 | .27 | 0.2 |
| III | 1:3:1 | 18.0 | 15.4 | 2.77 | .52 | .03 | .13 | .09 | 10 | .38 | 22 |
| | 2:2:1 | 14.6 | 14.4 | 2.11 | .87 | .15 | .09 | .06 | 11 | .39 | 0.5 |
| | 3:1:1 | 13.5 | 13.0 | 1.75 | .81 | .21 | .03 | .07 | 15 | .27 | 0.2 |
| IV | 1:3:1 | 18.0 | 15.4 | 2.77 | .52 | .03 | .13 | .09 | 10 | .38 | 22 |
| | 1:½:1 | 18.4 | 14.4 | 2.63 | .76 | .13 | .06 | .13 | 14 | .37 | 12 |
| IVa | 1:2:2 | 17.9 | 15.9 | 2.85 | .54 | .04 | .10 | .16 | 12 | .39 | 25 |
| | 1:⅓:2 | 16.8 | 13.4 | 2.29 | .55 | .14 | .03 | .25 | 12 | .36 | 8 |
| V | 1:1:3 | 14.9 | 14.8 | 2.08 | .63 | .06 | .06 | .25 | 10 | .40 | 24 |
| | 1:1:½ | 14.6 | 14.4 | 2.11 | .87 | .15 | .09 | .06 | 11 | .39 | 0.5 |
| VI | 3:1:1 | 13.5 | 13.0 | 1.75 | .81 | .21 | .03 | .07 | 15 | .27 | 0.2 |
| | ½:1:1 | 17.9 | 15.9 | 2.85 | .54 | .04 | .10 | .16 | 12 | .39 | 25 |
| Amount of difference needed for significance | | 2.9 | 1.6 | 1.1 | | | | | | | |

*The Yamada Soil:*

Contrary to expectations, the Yamada soil showed a response to both phosphate and potash; the reason for this is not apparent. When N was held constant (Group I) the low ratios of P to K produced slightly poorer cane yields; the cane quality was significantly poorer only when no phosphate was supplied.

With P constant (Group II) a change from a 2:2 ratio of N:K to either a 1:3 or a 3:1 ratio, gave poorer cane yields. With K constant (Group III) a 1:3 ratio of N to P shows increased cane yields over a 2:2 or a 3:1 ratio.

With a 1:1 ratio of N to K (Group IV) there was no reliable difference in cane or quality with changes in the P ratio; however, with a 1:2 ratio (Group IVa) of N to K the quality was better when P was high.

No differences in yield or quality are shown when the ratio of K to a constant N:P ratio is changed (Group V) but when the N ratio associated with a 1:1 P:K ratio (Group VI) is increased, both cane yield and quality are adversely affected.

Again, it will be noted that the percentage of N, $P_2O_5$, and $K_2O$ in the crusher juice follow quite nicely their respective amounts supplied in the fertilizer. Glucose also followed the changes in the nitrogen ratios.

TABLE VI

COMPARING THE PRINCIPAL YIELD VALUES OBTAINED FROM VARIATIONS IN THE N:P:K RATIOS ON THREE DIFFERENT SOILS

| | | | Manoa soil | | Makiki soil | | Yamada soil | |
|---|---|---|---|---|---|---|---|---|
| | | Ratios | ℔ cane | Q.R.* | ℔ cane | Q.R.* | ℔ cane | Q.R.* |
| A: | (N:P:K) | N:P+K | | | | | | |
| | (1:3:1) | 1:4 | 17.5 | 6.6 | 13.4 | 6.8 | 18.0 | 6.5 |
| | (1:2:2) | 1:4 | 18.2 | 6.6 | 15.6 | 6.9 | 17.9 | 6.3 |
| | (1:1:3) | 1:4 | 17.4 | 6.6 | 16.8 | 6.9 | 14.9 | 6.8 |
| | (1:⅓:2) | 1:2⅓ | 17.7 | 6.6 | 18.6 | 7.1 | 16.8 | 7.5 |
| | (2:1:2) | 2:3 | 20.6 | 7.7 | 15.0 | 7:3 | 18.4 | 6.9 |
| | (2:2:1) | 2:3 | 18:3 | 7.0 | 13.0 | 7.3 | 14.6 | 6.9 |
| | (3:1:1) | 3:2 | 16.3 | 7.0 | 16.8 | 7.3 | 13.5 | 7.7 |
| B: | (N:P:K) | P:N+K | | | | | | |
| | (1:⅓:2) | ⅓:3 | 17.7 | 6.6 | 18.6 | 7.1 | 16.8 | 7.5 |
| | (1:1:3) | 1:4 | 17.4 | 6.6 | 16.8 | 6.9 | 14.9 | 6.8 |
| | (2:1:2) | 1:4 | 20.6 | 7.7 | 15.0 | 7.3 | 18.4 | 6.9 |
| | (3:1:1) | 1:4 | 16.3 | 7.0 | 16.8 | 7.3 | 13.5 | 7.7 |
| | (1:2:2) | 2:3 | 18.2 | 6.6 | 15.6 | 6.9 | 17.9 | 6.3 |
| | (2:2:1) | 2:3 | 18.3 | 7.0 | 13.0 | 7.3 | 14.6 | 6.9 |
| | (1:3:1) | 3:2 | 17.5 | 6.6 | 13.4 | 6.8 | 18.0 | 6.5 |
| C: | (N:P:K) | K:N+P | | | | | | |
| | (1:3:1) | 1:4 | 17.5 | 6.6 | 13.4 | 6.8 | 18.0 | 6.5 |
| | (2:2:1) | 1:4 | 18.3 | 7.0 | 13.0 | 7.3 | 14.6 | 6.9 |
| | (3:1:1) | 1:4 | 16.3 | 7.0 | 16.8 | 7.3 | 13.5 | 7.7 |
| | (1:2:2) | 2:3 | 18.2 | 6.6 | 15.6 | 6.9 | 17.9 | 6.3 |
| | (2:1:2) | 2:3 | 20.6 | 7.7 | 15.0 | 7.3 | 18.4 | 6.9 |
| | (1:⅓:2) | 2:1⅓ | 17.7 | 6.6 | 18.6 | 7.1 | 16.8 | 7.5 |
| | (1:1:3) | 3:2 | 17.4 | 6.6 | 16.8 | 6.9 | 14.9 | 6.8 |

* The reciprocal of the Y%C figures previously used in Tables III, IV, and V.

*All Three Soils:*

If we attempt to bring together those N:P:K ratios which are associated with the higher sugar yield figures from the three soils, we have a picture like this:

| On the Manoa soil | | On the Makiki soil | | On the Yamada soil | |
|---|---|---|---|---|---|
| Ratio | (℔ sugar) | Ratio | (℔ sugar) | Ratio | (℔ sugar) |
| 1:2:2 | (2.76) | 1:⅓:2 | (2.63) | 1:2:2 | (2.85) |
| 1:⅓:2 | (2.67) | 1:0:4 | (2.48) | 1:3:1 | (2.77) |
| 1:3:1 | (2.64) | 1:1:3 | (2.42) | 2:1:2 | (2.63) |
| 1:1:3 | (2.64) | | | | |

Other than the fact that a low nitrogen ratio appears to be predominantly associated with the better sugar yields, it is doubtful whether any specific phosphate or potash ratios are similarly associated.

The evidence of these "best" ratios is certainly not in conformity with our knowledge of the sugar cane plant's requirements on these three soils. For instance, if the "best" ratio indicated for the Manoa soil is placed on a basis of pounds of each nutrient needed per acre, using 150 pounds of N as the most economical base, the complete fertilization would call for 150 pounds N, 300 pounds $P_2O_5$, and 300 pounds $K_2O$, and this would not be far from the known requirements. But on this same basis, the next best ratio would call for 150 pounds N, 50 pounds $P_2O_5$ and 200 pounds $K_2O$, and this amount of $P_2O_5$ and also of $K_2O$ is considered inadequate for a satisfactory crop at Manoa.

On the Makiki soil, where at least 200 pounds of N is essential for a maximum yield, the "best" ratio would call for 200 pounds N, 66 pounds $P_2O_5$ and 400 pounds of $K_2O$. This would provide an enormous waste of potash on this soil which is adequately supplied with potash from its natural sources.

Similarly, on the Yamada soil, where 200 pounds of N can be economically used, the "best" ratio would appear to call for 200 pounds N, 400 pounds $P_2O_5$, and 400 pounds $K_2O$; again too much P and K.

Thus in practical parlance, sugar yields which were not significantly different were secured when ratios were used which would call for total applications (pounds of N, $P_2O_5$, and $K_2O$ per crop) of approximately these magnitudes:

| On the Manoa soil | | | On the Makiki soil | | | On the Yamada soil | | |
|---|---|---|---|---|---|---|---|---|
| lb N | lb $P_2O_5$ | lb $K_2O$ | lb N | lb $P_2O_5$ | lb $K_2O$ | lb N | lb $P_2O_5$ | lb $K_2O$ |
| 150 | 300 | 300 | 200 | 66 | 400 | 200 | 400 | 400 |
| 150 | 50 | 300 | 200 | 0 | 800 | 200 | 600 | 200 |
| 150 | 450 | 150 | 200 | 200 | 600 | 400 | 200 | 400 |
| 150 | 150 | 450 | | | | | | |

When a comparison of the relative effects upon cane yield and quality ratio secured from these three different soils is made in such a way that it shows the relationship between any single nutrient and the combined amounts of the other two nutrients (i.e., the ratio of N to P and K combined; of P to N and K combined; and of K to N and P combined) as in Table VI, there is little evidence to clarify an already complicated picture.

Even when we attempt to summarize the results of the major changes in a somewhat qualitative manner, as in Table VII, the data do not apparently furnish us with a reliable conclusion which we can evaluate and make practical use of, except perhaps that the results would appear to be the effects of a higher amount of N in the ratio.

From these tabulations, therefore, it is apparent that the effects are not always alike on different soils, and that it would be extremely hazardous to predict either an optimum ratio or the effect of any specific N:P:K ratio that might be supplied in a complete fertilizer mixture.

TABLE VII

SOME COMPARATIVE EFFECTS FROM THE MAJOR SPECIFIC CHANGES IN THE N:P:K RATIO

| A—Condition: A change in the N:P:K ratio | Manoa soil Cane yield | Manoa soil Quality | Makiki soil Cane yield | Makiki soil Quality | Yamada soil Cane yield | Yamada soil Quality |
|---|---|---|---|---|---|---|
| I..........from 1:3:1 to 1:1:3 | = | = | + | — | —S | — |
| II..........from 1:1:3 to 3:1:1 | — | — | = | —S | — | —S |
| III..........from 1:3:1 to 3:1:1 | — | — | + | —S | —S | —S |
| IV..........from 1:3:1 to 1:½:1 | +S | —S | = | —S | = | — |
| IVa..........from 1:2:2 to 1:⅓:2 | = | = | + | — | — | —S |
| V..........from 1:1:3 to 1:1:½ | + | — | — | —S | = | = |
| VI..........from 3:1:1 to ½:1:1 | + | + | = | +S | +S | +S |

B—Varied plant food ratios:
(Basic ratio 1:2:2)

| Constant (1) | Increased (3) | Decreased (1) | Effect on quality: On Manoa soil | On Makiki soil | On Yamada soil |
|---|---|---|---|---|---|
| N | $P_2O_5$ | $K_2O$ | = | + | = |
| N | $K_2O$ | $P_2O_5$ | = | = | — |
| $P_2O_5$ | N | $K_2O$ | + | = | — |
| $P_2O_5$ | $K_2O$ | N | +S | +S | = |
| $K_2O$ | N | $P_2O_5$ | = | = | — |
| $K_2O$ | $P_2O_5$ | N | + | +S | + |

Legend:
= No effect, i.e., less than the standard error.
— Poorer by an amount greater than the standard error.
+ Better by an amount greater than the standard error.
S Significant, i.e., greater than twice the standard error of a difference.

*Tasseling:*

The plants which were grown in this test afforded an opportunity to investigate the effect of various plant food ratios upon the tendency to produce tassels. The results are summarized in Table VIII. They indicate that a somewhat higher percentage of the stalks grown on the Yamada soil produced tassels than those grown on either of the other soils. The most apparent difference between these soils is one concerned with their physical characteristics—the Yamada soil being especially difficult to drain.

As a generalization, it would appear that there was a lower rate of tasseling when the ratio of K to N and P was low; with equal N and P, low K showed negligible tasseling.

With equal amounts of N and K, the results from high and from low P on the three soils were quite dissimilar. With a 1 to 2 ratio of N to K there was less tasseling with the lower amount of P.

With equal amounts of P and K, the higher amount of N showed a negligible amount of tasseling on all soils.

TABLE VIII

PER CENT TASSELING

| Group | N:P:K ratio | Manoa soil | Makiki soil | Yamada soil |
|---|---|---|---|---|
| I | 1:0:4 | — 1 | 12 | 40 |
| | 1:1:3 | 16 | 21 | 24 |
| | 1:2:2 | 12 | 26 | 25 |
| | 1:3:1 | 0 | 0 | 22 |
| | 1:4:0 | 21 | 11 | 31 |
| II | 1:1:3 | 16 | 21 | 24 |
| | 2:1:2 | 13 | — 1 | 12 |
| | 3:1:1 | 0 | 0 | — 1 |
| III | 1:3:1 | 0 | 0 | 22 |
| | 2:2:1 | 0 | — 1 | — 1 |
| | 3:1:1 | 0 | 0 | — 1 |
| IV | 1:3:1 | 0 | 0 | 22 |
| | 1:½:1 | 13 | — 1 | 12 |
| IVa | 1:2:2 | 12 | 26 | 25 |
| | 1:⅓:2 | 7 | 12 | 8 |
| V | 1:1:3 | 16 | 21 | 24 |
| | 1:1:½ | 0 | — 1 | — 1 |
| VI | 3:1:1 | 0 | 0 | — 1 |
| | ½:1:1 | 12 | 26 | 25 |
| Average tassel ........ | | 8 | 9 | 18 |

*Summary:*

Studies of data previously collected had indicated a rather consistent and uniform ratio of N:P:K in the sugar cane plant.

The present study aimed to determine whether there might be such a thing as an optimum ratio of N:P:K which when used in a complete fertilizer mixture would give optimum yields.

Various ratios of N:P:K were tried on three quite different soils.

Results secured, in terms of sugar yields obtained, were not significantly different when some rather wide differences in the N:P:K ratios were used.

Those ratios which were found to be associated with the "best" yields were not generally in conformity with the known requirements of the three soils which were studied. Thus there is little encouragement brought forth that an optimum N:P:K ratio for a complete fertilizer mixture can be specified.

Crusher juice analyses showed a positive relationship with the respective nutrient ratios which were supplied. High glucose was associated with high nitrogen in the juice, which in turn was the effect of high nitrogen in the fertilizer ratio.

The effects of the various ratios upon tasseling indicated lower percentages of tasseling (1) when K was low in proportion to N and P, and (2) when N was high in relation to P and K; hence a suggestion that low potash and high nitrogen provide a nutrient relationship which is not conducive to abundant tasseling.

# Colloids in the Sugar Mill

By Hugo P. Kortschak

In recent years it has been recognized that many of the difficulties of raw sugar manufacturing are caused by the presence of material in the colloidal state. Armed with this knowledge, engineers and chemists, and the salesmen of patent cure-alls, have devised countless methods for removing these colloids or rendering them harmless. Few of these methods have achieved general recognition, and none is suitable for all purposes and conditions.

That this is so should be no cause for surprise. Our knowledge of the complicated and ever-changing mixtures which we call cane juices is very vague. Seldom do we know just what it is that we wish to remove, or even why.

Where do these colloids come from? The sources may be divided into three classes. First, those which exist in the juice of the cane plant itself, and those which come from the cane stalk, we will call "inherent colloids." Second, there are the "extraneous colloids," coming from all the material entering the mill in addition to the cane stalk. Third, in the processes of manufacture, colloids may be formed. These we will call "process colloids."

## I. Inherent Colloids

*Pectin:*

This is one of the most important substances which exists in the juice in colloidal form. The basic unit of all pectic bodies is pectic acid, a ring structure of four galacturonic acid groups. Galacturonic acid is probably formed in the plant by the oxidation of the sugar galatose, from which it differs only by the presence of a carboxyl instead of the terminal alcoholic hydroxyl group.

Pectin itself is the form found in solution in the juice of the plant. It differs from pectic acid in that some of the carboxyl groups are esterified with methyl alcohol, which amounts to 10-12 per cent of the total. In addition, acetic acid, galactose, arabinose, xylose, araban, and cellulose may be combined with the ring. Pectins from various sources differ in composition as far as these additional groups are concerned. Since this is so, the exact constitution of sugar cane pectin will not be known until analyses have been made.

In the plant, most of the pectin is combined with the cell walls. In the sugar beet, this "protopectin" is in the form of a calcium—magnesium salt (11). Various means may be used to release the pectin from the fiber; for instance, heating with water, dilute acid, or salt solutions. This makes it certain that some pectin will be thus set free during the process of extraction in the sugar mill, and added to that already naturally present in the juice.

The cane plant contains relatively little pectin, 0.2 per cent being about the average, as nearly as can be judged from the scattered data available, and 1 per cent about the maximum to be expected. This may seem to be a small amount, but its importance may be shown by the effect on the viscosity, a solution containing one

part in a thousand of pectin having a viscosity comparable to a 10 per cent sugar solution.

Recent work in this laboratory has shown that pectin will combine with an equal quantity of citric or aconitic acids. Since these are the chief organic acids of cane juice, some or all of the pectin, depending on the concentration relationships, will be in this form.

What effect this will have on the properties of the pectin, outside of a slight lowering of the viscosity, is not known.

Evidence has also been found that sugar cane pectin carries a small amount of silica, although this may be only an adsorbed impurity.

In alkaline solution, pectin is almost immediately hydrolyzed to pectic acid. In acid solution, this also takes place, but much more slowly.

A well-known property of pectin is its power of increasing the solubility of sucrose. Upon what characteristics of the pectin this depends is not known, but it may vary enormously. In jellies, one part of pectin may "carry" from 100 to 500 parts of sugar. Some workers believe that this power increases with increased methylation of the hydroxyl groups of the pectin nucleus.

Pectin may be removed from solution by alcohol, or high concentrations of salts, which exert a dehydrating effect. Heavy metals, such as lead, precipitate it. Calcium does not precipitate pectin itself, but the calcium salt of pectic acid is very insoluble, so much so that it is used for quantitative analysis. Calcium pectate is, however, more soluble in sugar solutions.

Any vegetable material entering the mill will contain some pectin, thus not only the cane itself, but (to a very small extent) the leaves and, of course, weeds and trash will contribute.

In the process of extraction, pectin will have a slight effect, in that the increased viscosity will make it more difficult to remove the last traces of juice from the bagasse. The treatment with hot water will extract some pectin from the fiber, as mentioned above. According to Farnell (12) the amount so extracted will be small.

When the juice is limed to alkalinity, the pectin is hydrolyzed to pectic acid, the reaction going to completion almost immediately when the juice is heated. The pectic acid reacts with calcium ions to form calcium pectate. The electric charge on pectin is negative both in alkaline and acid solution (18) so that there is no question of an isoelectric point in the pH range used in the sugar mill.

What the physical properties of this calcium pectate will be is hard to predict. Calcium and sodium ions are antagonistic as far as pectin solutions are concerned (14, 18). This means that each will tend to neutralize the effect of the other, and potassium will probably behave similarly to sodium. Stuewer (19) finds that magnesium pectate has greater powers of adsorption than the sodium or potassium salt, but the ratios vary widely with changes in concentration.

Despite its negative charge, which is also that of the calcium phosphate floc (9), some of the calcium pectate is doubtless absorbed by this floc and carried down with it. The major portion, however, remains in the juice. Fortunately, the viscosity of pectate solutions, although still great, is considerably less than that of pectin solutions of equal concentration. As an example, at room temperature a 0.1 per cent pectin solution will have a viscosity 1.30 times that of water; when hydrolyzed to sodium pectate, the relative viscosity falls to 1.15. Pectates as well as pectin will

combine with citric or aconitic acid, the viscosity decrease being proportionately the same in both cases.

In evaporation, the presence of pectic substances will have little effect, as the concentrations are too small to affect the vapor pressure appreciably. They do cause a lowering of the surface tension, which will increase foaming, and the higher viscosity makes efficient heat transfer more difficult.

In crystallization, the presence of pectates is very unfavorable. Not only is the actual solubility of sucrose increased, but higher viscosity will slow down the velocity of crystallization, besides slowing the cooling, because of the higher specific heat and less efficient heat transfer. The shape and the purity of the sugar crystals will also be affected.

*Pentosans:*

The pentosans or gums are polymers of the pentose sugars. Araban may be hydrolyzed to arabinose, xylan to xylose, etc. In the sugar cane, araban seems to be the chief pentosan, with xylan also present. As mentioned before, pentosans are combined in the pectin molecule; this may be one of the chief sources of these compounds in the cane juice. The investigation by Cook (9), as well as that of Smith (16), shows that gums in the juice increase after clarification, being extracted from the small fiber particles which are present. Free pentosans will naturally increase when the pectin is hydrolyzed, during which reaction they are released from combination.

As far as the effects of pentosans on the mill processes are concerned these are similar to those of pectin, but in lesser degree. Whether pentosans also increase the solubility of sugar has not, apparently, been experimentally established, but it seems most probable. Since the pentosans are not removed by clarification, while some of the pectin is, they may be of greater final importance.

The conditions of growth, as well as the variety of cane from which the juice comes can influence the quantity of gums present greatly. Diseased or damaged cane is particularly apt to form exceptional quantities of pentosans.

*Protein:*

The proteins of the cane juice are largely albumins. These substances are present mainly in the growing point and leaves, so that when tops enter the mill with the cane itself there is a considerable increase in the protein content of the juice. The albumins are coagulated by heat, and thus removed during clarification. The only influence of any importance that they can have is to increase the difficulty of filtration, due to the gel-like character of the coagulum. Such proteins as are not coagulated by heat will remain as lyophilic colloids, having much the same physical effects as the pentosans. To a considerable extent, they will be decomposed to the constituent amino acids which go into true solution.

Any protein has an isoelectric point. Most of these fall in the pH range of 4 to 6. The "salt effect" due to the presence of electrolytes may change the pH of the isoelectric point, so that measurements made in water do not apply to cane juice; nevertheless it seems certain that the isoelectric points of most proteins will be within the pH range used in the mill.

The coagulation of proteins can be very easily reversed in some cases, usually by the addition of alkali (1). Here is a reaction which might well occur during clarification. To demonstrate the complex nature of protein coagulation, we may mention that albumin which has been extracted with ether is not coagulated by heat (2).

*Wax:*

Wax is one of the most important colloids in normal juices. Since wax is hydrophobic, some as yet unknown substance (probably the gums) must act as a protective colloid to cause its dispersion in the acid juice. This will be aided by the raised temperature of extraction, which is high enough to melt the wax, so that it forms a colloidal emulsion.

Cane wax consists mainly of myricyl alcohol, $C_{30}H_{61}OH$, esterified with caproic, stearic, and palmitic acids. According to Bardorf and Ball (5, 3; also Smith, 17), there are two waxes present. One is green, acetone soluble, melting at 52°; the other, alcohol soluble, melting at 82°.

Wax is, along with the fat, the major cause of the turbidity of clarified juice. According to Smith (16) and Bardorf (4), as much as 1 per cent of the solids of clarified juice may consist of wax, or, more correctly, of wax and fat.

The wax appears to be very little influenced by any of the processes, appearing apparently in the original state, as the main organic colloid in refined sugar. Judging from the difficulty of saponifying other waxes, it is probably left unchanged by clarification. Once deposited on any surface, it clings tenaciously and is difficult to remove. Thus, besides adding to the difficulty of filtration, the wax will also be deposited on the surface of the sugar crystals as they are formed, and continue on to the refinery.

*Fats and Fatty Acids:*

A considerable search of the literature has failed to reveal any recognition of certain substances present in cane juice as fats. They have always been treated as part of the cane wax. Whether or not one or even both of the "waxes" found is really a fat is not known. Since they were largely saponifiable, this is not only possible but probable.

These fats consist of glycerides of palmitic and stearic acids. That they are easily saponified is a fact of some importance, as in the process of clarification the fatty acids are set free, forming soaps (16, 17). It is well known that calcium soaps have little or no detergent power, and this would make it seem as if the soaps formed would not be very harmful. It must not be forgotten, however, that there is a considerable concentration of potassium ions in the juice. When both calcium and alkali ions are present in a soap solution, the properties of the soap depend upon the ratio of the concentrations of these ions. If there is an excess of potassium ions, the properties of the compound will be more or less similar to those of a pure potassium soap (13, p. 41). We must not lose sight of the fact that there are other ions in the solution, too, any of which may be antagonistic to calcium or potassium, or to any other. Thus, prediction as to what extent the properties of the soap will be more nearly like those of potassium or calcium becomes impossible. Probably different forms will predominate in different samples of clarified juice.

The fact that most of the soap may be removed by filtration is difficult to understand. Two explanations may be advanced. Either the calcium salt form predominates, and the compounds are coagulated into relatively large particles, or else the soap is adsorbed on the surface of fine particles of fiber or other suspended matter. That the soap is so adsorbed can be shown by the decrease in fat content of the juice when it is screened to remove the fiber particles. This tends to make the second explanation more plausible. Here again it is possible that either explanation may hold, depending upon the conditions.

The difficulties which will be caused by the presence of soap in the juices need little elaboration, since its common use is due to the power of dispersing insoluble "dirt" in water. Any possible effect on the crystallization of the sugar is unknown, except that some of the soap will be adsorbed on the surface of the crystals.

*Polyphenols:*

Those impurities in the juice which are usually called "coloring matter" and "tannins" are chemically so similar that they may well be treated together. They consist of polyphenolic compounds, largely of the catechin type. They are usually present in such small amounts as to be unimportant. When they are present in larger quantities, as is the case with some varieties of cane, combination takes place with traces of iron in the juice to form dark-colored inks. No other influence of importance, besides that on the color of the product, can be ascribed to these substances.

The major portion of the polyphenolic compounds is removed by lime clarification. They are probably adsorbed on the calcium phosphate floc as calcium salts.

The source of these compounds is, in the case of the anthocyan coloring matter, the colored portion of the cane. The tannins are also present in the interior and in the juice. Injury to the cane plant may cause a large increase in tannin content.

*Starch:*

Most cane varieties contain little or no starch, but in a few this carbohydrate reaches considerable proportions. During extraction the starch passes into the juice. A typical lyophilic colloid, its properties resemble those of pectin, except that (1) the effect on the viscosity is much smaller, (2) there is no combination with citric or aconitic acid, and (3) it is not hydrolyzed during clarification. Although starch has been blamed for the poor clarifying properties of some juices, no case seems to have been proven. It would seem that starch concentrations high enough to be troublesome are most unlikely to occur. In one case at least, where difficulties were ascribed to starch, another compound, a glucose decomposition product, was found to be the real cause of the trouble.

## II. Extraneous Colloids

*Humus:*

Of all the extraneous colloids, those which may cause the greatest difficulty are those derived from the soil. That this is so has been made evident when very large quantities of earth have been allowed to enter the mill. This is not the place for an extended treatment of the colloid chemistry of soils, so only a brief discussion will be given.

Humus is the name given to all the decomposed plant remnants which are present in the soil. Its constituents will include everything from still recognizable portions of leaves to bubbles of entrapped carbon dioxide gas, an end product of organic oxidations. An important group of constituents are the humic acids. These are often present as insoluble calcium salts which become colloidally soluble when the calcium is removed. This may possibly occur during extraction. Other portions of the humus are already present as hydrated colloidal particles, sometimes in the form of a film, coating the inorganic portion of the soil (10).

From the humus, lyophilic colloidal material passes into the juice, where it will exert the usual effects of such colloids, i.e., increase in viscosity, more difficult filtration, etc. Where humic acids are present, these will be precipitated by lime. Other compounds may not be so easily eliminated. Of course, any compound occurring in the plant, except the very unstable ones, will be found in the humus.

*Inorganic Colloids:*

Coming largely from soil, the inorganic colloid content of juices can vary greatly. The oxides and silicates of iron and aluminum make up the bulk of this material. These substances form, in the most part, hydrophobic colloidal suspensions which are very easily broken. In the presence of hydrophilic colloids, organic or inorganic, however, these inorganic particles are coated with an adsorbed layer of hydrophilic material, and thus they have, for all practical purposes, the properties of the protecting colloid. In clays, especially, this is already the case with the soil in its original state. Like a lyophilic colloidal solution, a protected lyophobic solution cannot be precipitated by minute concentrations of electrolytes, as the neutralization of the electric charge still leaves the protecting adsorbed water layer to prevent coagulation.

The same statements will apply to any inorganic colloids which may be formed during clarification. Positive evidence of such formation is lacking, but since it is very difficult to prevent colloidal solutions from forming even under laboratory conditions, there can be no doubt that colloidal calcium phosphate, to name but one, must be present in clarified juice.

The great importance of the colloids derived from the soil lies in the possibility of enormous quantities entering the mill under exceptional conditions. In such a case, all other colloidal constituents of the juice lose their importance, except as protective agents. It is fortunate that most of the soil particles will not be of colloidal size, as a rule, so that they will settle, though slowly, and not contribute too greatly to the viscosity.

Such inorganic colloidal matter as reaches the crystallizer will be quite as deleterious as the organic. Considerable quantities of sucrose are adsorbed even by hydrophobic minerals in the colloidal state (6).

In water, the isoelectric point of the oxides and silicates is near neutrality. For alumina, for instance, it is at pH 8.1. Thus, when other stabilizing factors are not present, such colloids will flocculate during clarification. It must not be forgotten that such flocculation under isoelectric conditions may take place although hydrophilic colloids are present. Even when the exact conditions are known, it is not always simple to predict whether an isoelectric solution will coagulate. In such a complex mixture as cane juice, it is impossible.

*Other Colloids:*

The various classes of material which have been mentioned do not, by any means, complete the possible colloidal substances which may enter cane juice.

When the cane is burned, products of polymerization, decomposition and oxidation are formed, whose nature will vary in each case to produce results which cannot be predicted with the amount of information available at present.

When weeds enter the mill in large quantities, they, too, will contribute to the juice. Except in the case of unusual plants, this will involve only an increase in the amounts of pectin, pentosan, starch, protein and polyphenols, but the possibility of completely new complicating factors can never be ruled out except by a study of the plant involved.

Fertilizers, insecticides, and weed sprays must also be remembered, especially in connection with their influence upon the properties of the soil.

## III. Process Colloids

Many of the substances already discussed might be placed under this heading, since they are not in the colloidal state until after the process of extraction. However, it seems more convenient to consider the "mill processes" as beginning with the mixed juice.

*Glucose Decomposition Products:*

"Nef has shown that glucose in the presence of sodium hydroxide reacts to yield an equilibrium mixture containing at least 93 different compounds, and concluded that (1) the initial fragments undergo molecular rearrangement to form more stable compounds, (2) they may react with each other, one being oxidized and the other reduced, (3) they may combine or polymerize, and (4) they may react with other substances, such as oxygen, to form acids, etc." (13, p. 633.)

A very small amount of glucose is always present in solution in a specially active form. The rate of formation of this form increases proportionately to the hydroxyl ion concentration; it is increased 100 times for a 22° rise in temperature (8, 15). Thus, the rate of formation will be increased about a billion ($10^9$) times when a glucose solution at room temperature and pH 5 is brought to 100° and pH 8. This active glucose appears to undergo all the reactions of ordinary glucose, only at a greatly increased rate. (No reference to an active form of fructose appears to exist; from theoretical considerations there should be one, similar in properties to the active glucose.)

The multiplicity of the decomposition products of glucose makes it difficult to evaluate their effect upon the juices. Many of them are truly soluble; for instance, glycolic, formic, and oxalic acids. Other products, such as glyceric acid and saccharinic acid, especially in the form of their calcium salts, may have more nearly colloidal properties. The glucose decomposition products include many of dark color, and many which form highly viscous solutions.

*Sugar Salts:*

Sucrose itself may be considered a "border-line case" as far as the distinction between colloidal and true solutions is concerned. The calcium salts, not only of sucrose, but of glucose as well, have even more the properties of colloids.

Any saccharate will not, of course, crystallize out as sucrose. Outside of this, and the greater activity of the salts as compared with the sugars themselves, the effect of the salts will be similar to that of other hydrophilic colloids. Only small amounts of lime salts will be present under the usual conditions of clarification, for the sugars, viewed as acids, are very weak indeed, almost as weak as water. Note, however, that active glucose is a much stronger acid than is the normal form.

## IV. The Influence Of Colloids On Mill Processes

The presence of colloids in the sugar mill exerts an unfavorable influence from the first process to the last. In extraction itself the effect is relatively minor, being due to the increased viscosity and stickiness of the juice, which tends to cause more of it to remain with the bagasse. Throughout the manufacturing processes the raised viscosity is a great handicap, slowing down operations and increasing power requirements.

*Clarification:*

The colloid chemistry of clarification is both important and complicated. Due to increased viscosity, colloids increase the possibility of uneven liming. As a result of this, some portions of the juice will be temporarily raised to too high a pH, while in others the main precipitation will take place at a lower pH and lime concentration than was intended. This will cause variation in the physical, if not in the chemical, form of the floc, and thus cause changes in its powers of adsorption and "sweeping."

Lime is added for two largely independent reasons. First, to neutralize the acidity of the juice; second, to precipitate phosphate. It has often been said that lime precipitates many other acidic substances, such as oxalate and citrate. It is improbable, however, that the concentration of any acid, except phosphoric, reaches a point where the true solubility of the calcium salt is exceeded. (The presence of diseased or damaged cane, or of soil high in humic acids, may cause exceptions to this.)

The calcium phosphate precipitate is largely in the form of an acid salt. The electric charge of the phosphate is negative (7). Such a precipitate will carry down with it mainly positively charged substances. (The colloids in the juice are, of course, negatively charged.) This does not exclude the possibility of other insoluble calcium salts, which are not present in sufficient concentration to be precipitated by themselves, being removed by coprecipitation.

One often encounters the statement that the phosphate floc, as it settles, sweeps the juice clear of colloids. The crudest definition of colloids states that they will pass through filter paper, which disposes of this possibility. Coarser suspended particles will be removed in this way, but long before particles of colloidal dimensions are reached this has lost its efficiency, as can easily be seen by the amount of material which filtration removes from clarified juice.

It has quite commonly been accepted as a fact that some of the colloids in cane juice are coagulated by slight alkalinity. Since increasing alkalinity increases the negative charge on the colloids, this seems unlikely, except for such where, as with the proteins, the charge is due to ionization of an amphoteric substance and the isoelectric point is in the neighborhood of neutrality. When such an electrolyte is

on the acid side of the isoelectric point and the pH is raised, the positive charge becomes smaller, as the basic ionization is suppressed. This assumes that there has been no adsorption of negative colloids by the positive ones, making the total charge of these negative in conformity with the bulk of the colloids present. The isoelectric point of the albumins is too low (around pH 4.5) and they will be negatively charged even before the juice is limed.

The change of the juice to alkaline reaction will precipitate the hydroxides of aluminum and iron from solution. These hydroxides precipitate as slimy gels of great adsorptive power. As amphoteric substances, they will, in the moment of formation, bear a nearly zero charge, which will rapidly be made negative by the adsorption of negative ions and colloids. This adsorption may or may not cause the hydroxides to stay in such finely divided form as to remain in suspension. A part will, of course, be attracted to the negatively charged phophate floc, and thus removed.

The heating of the juice hastens the formation of larger particles of the precipitate. In addition, the temperature rise causes a great decrease in viscosity. These influences combine to cause an increase in the rate of settling, as, according to Stokes' Law, this rate is proportional to the square of the radius of the particles, and inversely proportional to the viscosity. The main influence of the hydrophilic colloids upon clarification lies in their action opposing these two tendencies. Adsorbed on the surface of small particles, they prevent their coalescence, due both to the surrounding water shell and to the repulsion caused by the electric charges. Due largely to this same water shell which increases the volume occupied by them, they raise the viscosity.

Another effect of the rise in temperature is the melting of the wax and fat, the liquid droplets being broken and dispersed still further by the violent agitation of the juice in its flow from the heaters to the settling tanks.

The albumins being unstable toward heat, they are dehydrated and coagulated, forming a gel-like precipitate which is carried down by the phosphate floc.

*Filtration:*

Difficulties in filtration are caused less by increased viscosity than by the presence of the adhesive gels which are formed in clarification. These adhere to the fiber particles which form the filter, clogging the pores, and making the passage of liquid impossible. The presence of large amounts of finely divided suspended matter of any kind has the same result. In addition, the gels which are present may hold relatively large amounts of water, thus causing loss of the sugar which is dissolved in it. Since a gel may contain as little as one part in a thousand of solid material, a small amount of impurity may immobilize a considerable volume of water. This water must not be confused with the "bound water" of hydrophilic colloids, which seldom exceeds 2—3 times the volume of the solid core.

*Evaporation:*

The colloids have practically no effect upon the vapor pressure of the juice. Raised viscosity causes uneven heating, and local superheating, with resultant "bumping." Reduced surface tension causes foaming.

Due to the increasing concentration of the solution, such substances with which

the juice is saturated, for example calcium phosphate, will precipitate. Since these materials are present in extreme dilution, the precipitates are likely to remain in colloidal form.

*Crystallization:*

After evaporation, the colloidal characteristics have greatly changed, largely due to the formation of new material by the decomposition and oxidation of glucose and other substances. (Among these products may be oxalic acid, in the form of the very insoluble calcium salt, sometimes found as scale on the boiler walls.) The colloidal constituents of the massecuite do not appear to have been investigated except from the standpoint of total colloid content.

The presence of colloidal material will influence the shape and size of the sugar crystals, as well as their purity. The last is lowered by solid material, mostly the fatty acid soap, adsorbed on the crystal surface (17), as well as by increasing the amount of molasses adhering to the crystals. It may be well to point out that, since the crystals grow slowly, material adsorbed on the surface does not necessarily remain there, but may be in the interior of the final crystal.

The mechanism by which lyophilic colloids prevent the crystallization of a considerable part of the sugar present is still a matter of controversy. Important as this is to the sugar industry, investigations of this subject have been largely empirical attempts to remove either colloids or sugar from the molasses. The surprising constancy of the sucrose content of molasses from different factories leads one to the belief that the problem may not be as complicated as it would appear to be.

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# The Availability of Insoluble Phosphates to Sugar Cane

By A. S. Ayres

## Introduction

Phosphates are present in soils in many forms and combinations. In agricultural soils these occur in part naturally and in part from the interaction of added phosphate fertilizers with various constituents of the soil. Where it has been the practice to employ insoluble phosphate fertilizers, these may be present to some extent in much the same forms in which they were originally applied. All of these soil phosphates are very insoluble, as is attested by the extremely low concentrations of this nutrient in water extracts of soils and in drainage waters, even when these have originated in fields abundantly supplied with phosphorus.

In 1933, P. L. Gow and R. R. Ward, at this Experiment Station, conducted an experiment which was designed to show to what extent some of the simpler insoluble compounds of phosphorus presumably present in soils and certain insoluble commercial forms of phosphate were available to sugar cane. This was accomplished by growing cane plants in quartz sand cultures in which the only sources of phosphorus available to the plants were those under consideration. The insoluble forms of phosphate studied by these workers were raw rock, commercial reverted, and the phosphates of iron, aluminum and calcium. In order to compare the availability of these insoluble forms of phosphate with soluble forms, pots receiving sodium phosphate and calcium superphosphate were included in the test. The results of the experiment showed that all of the insoluble phosphates, except raw rock, were equally available to sugar cane. Moreover, they were fully as available as the soluble forms. The plants, which were fertilized with raw rock phosphate, were found to grow slower during the first months of the experiment than the other treated plants, thus indicating, apparently, a lower availability of phosphorus from this source. Subsequently, however, as though phosphorus were being made available at a greatly increased rate, the plants treated with raw rock phosphate began to grow much more rapidly—more rapidly, in fact, than the canes in any of the other treatments.

In 1935 the writer was assigned the task of carrying this research a step further by determining the degree to which certain forms of insoluble commercial phosphates employed in the study just cited are available to sugar cane when grown in soil instead of in sand cultures. It is with this experiment that the present paper deals.

## Experimental

Since raw rock and reverted phosphates are the only insoluble forms of this nutrient which have been used to any great extent on Island plantations, it was decided to limit the experiment to the consideration of these two forms. To serve as a criterion of the growth resulting from the use of these phosphates, a series of pots in which calcium superphosphate was the source of the element was included in the study. The ability of the soil to furnish the cane with phosphate from its own natural supply was to be determined by inclusion of a series of pots to which no phosphate would be added. Acting upon the observation of Gow and Ward that

the phosphorus from raw rock phosphate becomes available to sugar cane slowly at first, but later at a more rapid rate, a treatment was included in the test which consisted of a mixture of raw rock and reverted phosphates. It was thought that if the situation observed in sand cultures by these men similarly obtained in the soil, the reverted phosphate would meet the immediate needs of the young plants and the raw rock phosphate the later requirements. In addition to these treatments, three others were included in the experiment, namely: superphosphate plus lime, reverted phosphate plus lime, and lime alone. The thought back of liming the soil was to determine, in the case of superphosphate, if the presence of a good supply of calcium in the soil would, upon the addition of the soluble phosphate, cause the formation of a relatively insoluble calcium phosphate which would be more readily available to the cane plant than the products of fixation which would result were the additional lime not present in the soil. Where lime was used in conjunction with reverted phosphate it was hoped to determine if the partial neutralization by the lime of the acid soil to be employed in the experiment would effectively retard the solution and resultant fixation of the phosphate in forms less available to the cane plant.

The selection of a soil suitable for the study was of primary importance. The vital requirement was that the soil be sufficiently low in available phosphate to allow possible differences in the availabilities of the phosphates employed in the experiment to be reflected by corresponding differences in cane growth. For, manifestly, if the soil already contains sufficient phosphate to meet the needs of the crop, the addition of more phosphate, regardless of its availability, will not result in greater growth except, possibly, through some secondary effect upon the fertility of the soil. This is a point which is apt to be lost sight of in the planning of field experiments comparing raw rock with the various forms of soluble phosphates. Unless it can be shown that the soil under test is actually deficient in phosphate, as measured by crop response to fertilization with this nutrient, the mere failure to obtain more cane with soluble forms of phosphate than with raw rock does not prove that the two types are equally available.

Upon being advised that the soil of none of the cane lands on this island (Oahu) was sufficiently low in available phosphate to insure response to fertilization with this nutrient, the writer obtained soil samples from a dozen places at the Manoa Valley substation from which the necessary quantity of soil could be obtained. The suitability of the soils of the several locations was then determined by chemical analysis of the specimens. In the end it was necessary to resort to the use of a subsoil (Field 37, Manoa) in order to be sure of response even to soluble forms of phosphate. The analysis of the soil thus chosen is shown below:

ANALYSIS OF THE SOIL (MANOA) USED IN THE EXPERIMENT

| Determination | R.C.M.* | 1% citric acid soluble |
|---|---|---|
| $P_2O_5$ | Low | 0.0019% |
| CaO | ... | 0.015% |
| pH | 4.6 | ...... |
| Phosphate fixation | 90-90-20 | ...... |

* *Soil and Plant Material Analyses by Rapid Chemical Methods.* The Hawaiian Planters' Record, 40: 189-299, 1936.

$P_2O_5$: by extraction of soil with 0.5 N HCl.

pH: by modified LaMotte method.

Fixation: Figures refer to the percentages of applications of 1500, 7500 and 15,000 pounds $P_2O_5$ per acre-foot of soil fixed from neutral solutions of $(NH_4)_2HPO_4$.

Available for this study was a set of 32 large (2′ x 2′ x 2′) concrete pots which were set in the ground to a point a few inches from their rims. Drainage was provided by openings at the base of the pots through which drainage water might escape and be carried off.

After the soil selected for the experiment had been air dried and screened (½-inch mesh) the pots were filled to a depth of one foot and the soil thoroughly tamped down. All of the pots but those which were to receive lime were then filled to within 2 inches of the rim with more of the untreated soil. In the case of the lime treatments, the top foot of soil was thoroughly mixed with lime, in a mechanical mixer, at the rate of 9 tons per acre-foot of soil and placed in the proper pots.* Water was then added in order to bring about the reaction of the introduced lime with the acid soil. The limed soils were thus maintained in a moist condition for a period of 3½ months prior to fertilization and planting. For the sake of uniformity of treatment, the unlimed soils were also kept moist.

Shortly after the period allowed for the reaction between the soil and lime had elapsed, the top 6 inches of soil in the pots was dried and, in all but the control pots, removed, intimately mixed with the appropriate quantity and form of phosphate and returned to the pots. Phosphates were applied in this manner at the rate of 500 pounds $P_2O_5$ per acre-foot, based upon the surface area of soil in the pots. The eight treatments comprising the test were as follows (32 pots, allowing 4 replications of each treatment):

1. No phosphate
2. Superphosphate
3. Reverted phosphate
4. Raw rock phosphate
5. Reverted and raw rock phosphates in equal amounts
6. Lime — no phosphate
7. Lime — superphosphate
8. Lime — reverted phosphate.

The pots were planted with H 109 seed on August 2, 1935. Three weeks later the stand was thinned to 4 plants per pot. Nitrogen and potash in the form of Chile potash nitrate were applied monthly, beginning August 31, 1935, or 4 weeks after planting. The initial application of this material was 50 pounds per acre of nitrogen and potash. Succeeding monthly applications were 100 pounds per acre of nitrogen and potash. The small amount of replanting that was necessary was done at the age of 5 weeks with pregerminated seed. The plants for this purpose were obtained from flats of black sand which had been planted at the time the experiment was begun.

## Discussion of Results

*Notes on Growth—Symptoms of Phosphate Deficiency:*

Response to phosphate fertilization was apparent within 2 months from the time of planting, the treated canes making a more rapid growth and exhibiting a

* Preliminary laboratory tests showed that this amount of agricultural lime was required to bring the pH of distilled water, mechanically agitated with the soil for 10 days, to the neutral point, pH = 7.0. Six months after the lime was mixed with the potted soil, during which time nitrogen and potash were applied in amounts totaling 250 pounds each of N and $K_2O$ per acre from Chile potash nitrate, the reaction of the soil (in the limed controls) was pH = 6.0. At the same time that of the unlimed controls was pH = 4.8.


Fig. 1. Of the three pots in the foreground, the two containing four stalks each received no phosphate. The third pot received superphosphate. Note complete lack of secondary growth in the absence of added phosphate. Even at harvest only the four original stalks were present in the controls.

greener color than the controls. The lack of adequate phosphate in the controls was also evidenced by the complete failure of the canes in 7 of the 8 control pots to develop secondary growth. Development of secondary growth in the eighth control was confined to two of the four plants and was of a minor nature. This effect of phosphorus deficiency characterized these plants throughout the entire period of the experiment, only the 4 original stalks, with the exception noted, being present in each control at harvest. This point is illustrated in Fig. 1. At no time during

the experiment were any differences in growth apparent which could be attributed to the different forms of phosphate used. Lime appeared to be somewhat beneficial when employed together with phosphate.

*Procedure at Harvest:*

The cane from all treatments was harvested September 9-11, 1936, at the age of 13 months. Tops and millable cane were weighed separately and samples of each taken for analysis for phosphorus. Other portions of the stalks were ground and the resulting juice set aside for the determination of purity. The top 6 inches of soil, with which the phosphate had been mixed at the beginning of the experiment, was sampled for the determination of available phosphate.

*Availability of Soluble and Insoluble Phosphates as Measured by the Yield of Cane—Effect of Lime on Cane Yield:*

The weights of stalks and of tops harvested are shown in Table I. Referring to the table and considering first the unlimed soils, it will be seen that, judged by the growth produced, reverted and raw rock phosphates were about equally available to the cane plant. Moreover, these insoluble forms proved to be equally as available as (soluble) superphosphate. The response to all three forms of phosphate was very large, the yields in the treated soils being ten times those in the controls.

It will be noted that the findings of the present study are not in complete agreement with those of the experiment of Gow and Ward as regards the availability of raw rock phosphate. It is probable, however, that the highly acid soil employed in this test possessed greater power to bring this form of phosphate into solution than did the medium of the earlier experiment. Gow and Ward maintained the reaction of their nutrient solution between $pH = 7.0 - 8.0$. This suggests that while raw rock phosphate may be equally as available as soluble forms on acid soils, the same may be true on neutral or basic soils.

As in the unlimed soil, the insoluble phosphates proved to be equally as effective as the soluble form, so in the limed soils the single insoluble phosphate used (reverted phosphate) produced fully as much cane as superphosphate. The incorporation of lime into the soil did not, in the absence of added phosphate, result in significantly increased growth. However, where phosphate also was used, lime appears to have been beneficial. Thus, it will be observed in Table I that the average yields for super and reverted phosphates on the limed soil are considerably larger than for corresponding treatments on the unlimed soil. In the case of superphosphate, analysis of the data shows that the difference is probably a real one, while with reverted there seems no question but that increased growth resulted from the use of lime.

*Effect of Lime on the Quality of the Juice:*

In numerous experiments in the field large applications of lime to the soil have resulted in a marked lowering of the quality of the juice. In order to determine to what extent, if any, the gains in yield resulting from the use of lime in the present experiment were offset by poorer juices the purity of the juices from all treatments but the controls were determined.* The results of the analyses are shown in

* Insufficient cane was present in the controls for the determination of both $P_2O_5$ and juice quality. The former information was deemed more essential to the study.

TABLE I

GREEN WEIGHTS OF TOPS AND STALKS (LBS.)

| Treatments* | Pot | Tops | Stalks | Pot | Tops | Stalks | Pot | Tops | Stalks | Pot | Tops | Stalks | Avg. | Tops | Stalks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No phosphate | A-1 | 0.94 | 1.69 | B-1 | 1.13 | 2.56 | C-1 | 0.94 | 2.00 | D-1 | 0.81 | 2.06 | 1 | 0.96 | 2.08 |
| Superphosphate | A-2 | 7.56 | 22.38 | B-2 | 7.38 | 19.56 | C-2 | 7.31 | 24.38 | D-2 | 4.00 | 21.31 | 2 | 6.56 | 21.91 |
| Reverted phosphate | A-3 | 8.31 | 22.06 | B-3 | 8.31 | 26.75 | C-3 | 6.88 | 25.31 | D-3 | 6.25 | 17.56 | 3 | 7.44 | 22.96 |
| Raw rock phosphate | A-4 | 4.69 | 18.38 | B-4 | 6.63 | 21.88 | C-4 | 6.25 | 23.50 | D-4 | 6.81 | 21.75 | 4 | 6.10 | 21.38 |
| Reverted + raw rock phosphate† | A-5 | 8.31 | 20.56 | B-5 | 6.31 | 17.63 | C-5 | 6.94 | 21.19 | D-5 | 5.81 | 18.38 | 5 | 6.84 | 19.44 |
| Lime — no phosphate | A-6 | 1.00 | 1.75 | B-6 | 1.31 | 2.69 | C-6 | 1.44 | 2.94 | D-6 | 1.06 | 2.13 | 6 | 1.20 | 2.38 |
| Lime — superphosphate | A-7 | 8.75 | 24.38 | B-7 | 7.25 | 29.94 | C-7 | 8.00 | 25.13 | D-7 | 6.88 | 22.88 | 7 | 7.72 | 25.58 |
| Lime — reverted phosphate | A-8 | 9.69 | 35.31 | B-8 | 8.00 | 32.81 | C-8 | 8.81 | 25.00 | D-8 | 6.63 | 33.50 | 8 | 8.28 | 31.66 |

* 500 lbs. $P_2O_5$ per acre based on surface area of soil in pot.

† 250 lbs. $P_2O_5$ each.

TABLE II

APPARENT PURITIES OF THE JUICES AT HARVEST

| Treatment | Pot | Purity | Pot | Purity | Pot | Purity | Pot | Purity | Avg. | Purity |
|---|---|---|---|---|---|---|---|---|---|---|
| No phosphate | A-1 | * | B-1 | * | C-1 | * | D-1 | * | 1 | * |
| Superphosphate | A-2 | 89.76 | B-2 | 89.61 | C-2 | 88.66 | D-2 | 91.00 | 2 | 89.76 |
| Reverted phosphate | A-3 | 88.56 | B-3 | 90.06 | C-3 | 89.62 | D-3 | 89.15 | 3 | 89.35 |
| Raw rock phosphate | A-4 | 90.66 | B-4 | 92.17 | C-4 | 88.44 | D-4 | 88.03 | 4 | 89.83 |
| Reverted + raw rock phosphate | A-5 | 88.57 | B-5 | 90.57 | C-5 | 88.37 | D-5 | 87.96 | 5 | 88.88 |
| Lime† — no phosphate | A-6 | * | B-6 | * | C-6 | * | D-6 | * | 6 | * |
| Lime — superphosphate | A-7 | 88.15 | B-7 | 86.76 | C-7 | 88.44 | D-7 | 86.69 | 7 | 87.51 |
| Lime — reverted phosphate | A-8 | 90.84 | B-8 | 88.31 | C-8 | 88.55 | D-8 | 88.04 | 8 | 88.94 |

* Insufficient juice for the determination of purity.

† Agricultural lime—at the rate of 9 tons per acre to pots 6-8, inclusive.

Table II. Since the cane was ground in a small experimental mill, these data are not comparable with the results obtained by methods of extraction which are more complete. However, they serve well enough to compare the effects of the different treatments. Reference to the table fails to reveal any clear-cut effect of treatment upon the quality of the juice. In this experiment the soils were only limed to about $pH = 6.0$. It is possible that the effect of lime on the juice is only detrimental beyond a point not reached in this study.

*Effect of Fertilization With Phosphate Upon the Percentage of Phosphate in the Plant:*

Reference to Table III will show that the percentage of phosphate in the dry matter of the tops was increased by the applications of this nutrient to the soil. This was true for all forms of phosphate used and on both the limed and the unlimed soils. The stalks of the treated plants, however, failed to show a corresponding effect of fertilization with phosphate. At first glance this result may seem to be at variance with many of the results of juice and stalk analyses of canes from phosphate experiments (2). In general, but by no means always, these have shown higher percentages of phosphate with increasing applications of the nutrient.

In the present instance, the failure of fertilization with phosphate to result in higher percentages of the nutrient in the stalks is probably explainable upon the basis of the extremely phosphate-deficient and high fixing soil used in this experiment, and the moderate applications of phosphate made to the soil. While the increases in available soil phosphate resulting from fertilization were sufficient to supply the canes with ten or more times the quantity of phosphate available to the control plants, thus making possible corresponding increases in growth, yet they were apparently insufficient to allow both for the increased cane growth and at the same time for a measurable accumulation of phosphate in the stalks above the percentage level of that in the controls. In the field, on the other hand, it is probably safe to say that the majority of phosphate experiments are on areas which are not deficient in this nutrient and upon which further applications of phosphate, since they would not result in increases in cane growth, would tend to raise the percentage of the element in the plant. Higher percentages of phosphorus in the plant might also be expected to obtain on phosphate-deficient soils if the quantity of the fertilizer added were considerably more than enough to produce maximum growth. The principle underlying the foregoing discussion is stated by Russell (3) in essentially the following words: If growth is being retarded due to an inadequate supply of some nutrient, the first increments of the nutrient added give considerable increments of crop; subsequent ones give less. So, the percentage of the nutrient in the crop may be unchanged by the first increments, or even fall, as the nutrient supply increases. With subsequent increases, however, higher percentages of the nutrient in the crop may be noted.

The fact that the tops reflected the supplies of phosphate available to the crop while the stalks did not suggests that the leaves, or possibly the non-millable green-leaf section of the stalk, might prove to be more sensitive indicators of the phosphate status of the soil than the millable stalks or juice.

TABLE III

PERCENTAGE OF PHOSPHATE ($P_2O_5$) IN DRY MATTER OF TOPS AND STALKS

| Treatment | Pot | Tops | Stalks | Pot | Tops | Stalks | Pot | Tops | Stalks | Pot | Tops | Stalks | Avg. | Tops | Stalks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No phosphate | A-1 | 0.13 | 0.037 | B-1 | 0.14 | 0.029 | C-1 | 0.12 | 0.029 | D-1 | 0.12 | 0.033 | 1 | 0.13 | 0.032 |
| Superphosphate | A-2 | 0.16 | 0.029 | B-2 | 0.15 | 0.028 | C-2 | 0.17 | 0.029 | D-2 | 0.18 | 0.039 | 2 | 0.17 | 0.031 |
| Reverted phosphate | A-3 | 0.16 | 0.029 | B-3 | 0.18 | 0.024 | C-3 | 0.19 | 0.029 | D-3 | 0.18 | 0.035 | 3 | 0.18 | 0.029 |
| Raw rock phosphate | A-4 | 0.22 | 0.035 | B-4 | 0.18 | 0.029 | C-4 | 0.18 | 0.029 | D-4 | 0.17 | 0.029 | 4 | 0.19 | 0.031 |
| Reverted + raw rock phosphate | A-5 | 0.18 | 0.031 | B-5 | 0.18 | 0.033 | C-5 | 0.17 | 0.029 | D-5 | 0.17 | 0.037 | 5 | 0.18 | 0.033 |
| Lime — no phosphate | A-6 | 0.13 | 0.039 | B-6 | 0.12 | 0.030 | C-6 | 0.13 | 0.031 | D-6 | 0.12 | 0.034 | 6 | 0.13 | 0.034 |
| Lime — superphosphate | A-7 | 0.18 | 0.031 | B-7 | 0.15 | 0.029 | C-7 | 0.18 | 0.037 | D-7 | 0.19 | 0.038 | 7 | 0.18 | 0.034 |
| Lime — reverted phosphate | A-8 | 0.19 | 0.029 | B-8 | 0.18 | 0.031 | C-8 | 0.18 | 0.033 | D-8 | 0.17 | 0.032 | 8 | 0.18 | 0.031 |

TABLE IV

AVAILABLE (R.C.M.) PHOSPHATE IN THE SOILS AT HARVEST

| Treatment | Pot | $P_2O_5$ | Pot | $P_2O_5$ | Pot | $P_2O_5$ | Pot | $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|
| No phosphate | A-1 | Doubtful | B-1 | Low | C-1 | Low | D-1 | Low |
| Superphosphate | A-2 | Medium | B-2 | Doubtful | C-2 | Doubtful+ | D-2 | Doubtful |
| Reverted phosphate | A-3 | Medium | B-3 | Doubtful | C-3 | High+ | D-3 | High+ |
| Raw rock phosphate | A-4 | High+ | B-4 | Medium+ | C-4 | High+ | D-4 | High+ |
| Reverted + raw rock phosphate | A-5 | High+ | B-5 | High | C-5 | High+ | D-5 | High+ |
| Lime — no phosphate | A-6 | Low | B-6 | Low | C-6 | Low | D-6 | Low |
| Lime — superphosphate | A-7 | Doubtful | B-7 | Doubtful | C-7 | Doubtful | D-7 | Doubtful |
| Lime — reverted phosphate | A-8 | Doubtful | B-8 | Medium+ | C-8 | Doubtful+ | D-8 | Doubtful |

*Discussion of the Results of the Soil Analyses at Harvest:*

The analyses of the soils of the various treatments at harvest indicated supplies of phosphate ranging from "low" to "high plus" (see Table IV). The values of "low" were confined entirely to the controls. A result of "doubtful" for Control A-1 can not be explained. Since, however, the other 7 controls gave values of "low" for available phosphate, we shall presume that this value represents the true status of this element in the untreated soils. It will be noted in the table that there is a tendency for the soils treated with reverted phosphate to give higher values than those which received superphosphate. Where raw rock phosphate was used, either alone or in combination with reverted phosphate, the results are unquestionably higher. Now, reference to Table V will show that the plant material harvested from the various phosphate treatments (on the unlimed soil) contained about equal quantities of phosphorus. It seems reasonable to assume, therefore, that the roots and accumulated dead leaves from the various treatments contained approximately equivalent amounts of this nutrient. If this is true, then quantities of phosphorus of the same order were removed from the several phosphate treatments on the unlimed soils. Now, identical quantities of phosphate fertilizer were applied to these soils. Therefore, the different values obtained for soil phosphate at harvest can mean one of two things:

First, that part of the superphosphate was leached out of the top six inches of soil, with which it was mixed, to a greater degree than was either reverted or raw rock phosphate, with the result that this layer of soil at harvest contained less phosphate in the case of the superphosphate treatment than where the insoluble forms were used. In the light of the writer's study of phosphate fixation in Hawaiian soils (1), the high fixing power of the soil used in this experiment and the intimate mechanical mixing of the soil and superphosphate, it seems unlikely that an appreciable amount of the superphosphate was leached below the zone in which it was originally placed. Moreover, even if we were to admit the possibility of leaching of superphosphate in the unlimed soil, we should certainly expect such action to be arrested by the presence of calcium in the limed soil. Yet, reference to the superphosphate treatments in Table IV fails to indicate more phosphate in the fertilized zone of the limed soil than in that of the unlimed soil.

The second possibility is that the added phosphates were present in the soil at harvest, in part at least, in different forms—in forms either not equally soluble, or not soluble at the same rate, in the R.C.M. $P_2O_5$ reagent. To the writer this theory, that the different values obtained indicate not varying *amounts* of soil phosphate, but rather different *forms* of phosphate, seems the more plausible explanation.

It appears to follow, from this reasoning, that the higher R.C.M. values obtained on the soils treated with insoluble phosphates indicate the presence of greater or lesser portions of these fertilizers in much the same forms in which they were originally added to the soil. The lower values obtained on the superphosphate treated soils would then correspond to the solubility in the R.C.M. reagent of "fixed" phosphate, for there can be no doubt but that all but the minutest trace of the superphosphate would have been fixed under the conditions of the experiment months prior to the time at which the soils were sampled. If this postulate is correct, namely, that raw rock, and to a lesser extent, reverted phosphate were dissolved and fixed only in part after a year in a soil as acid as this one, and with

TABLE V

GRAMS $P_2O_5$ IN STALKS AND TOPS, PER POT

| Treatment | Pot | $P_2O_5$ | Pot | $P_2O_5$ | Pot | $P_2O_5$ | Pot | $P_2O_5$ | Avg. | $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|---|
| No phosphate | A-1 | 0.21 | B-1 | 0.26 | C-1 | 0.20 | D-1 | 0.21 | 1 | 0.22 |
| Superphosphate | A-2 | 2.03 | B-2 | 1.92 | C-2 | 2.12 | D-2 | 1.96 | 2 | 2.01 |
| Reverted phosphate | A-3 | 2.16 | B-3 | 2.46 | C-3 | 2.34 | D-3 | 2.00 | 3 | 2.24 |
| Raw rock phosphate | A-4 | 1.88 | B-4 | 2.05 | C-4 | 2.13 | D-4 | 2.08 | 4 | 2.03 |
| Reverted + raw rock phosphate | A-5 | 2.35 | B-5 | 2.01 | C-5 | 2.07 | D-5 | 2.01 | 5 | 2.11 |
| Lime — no phosphate | A-6 | 0.30 | B-6 | 0.28 | C-6 | 0.30 | D-6 | 0.25 | 6 | 0.28 |
| Lime — superphosphate | A-7 | 2.66 | B-7 | 2.29 | C-7 | 2.73 | D-7 | 2.64 | 7 | 2.58 |
| Lime — reverted phosphate | A-8 | 3.35 | B-8 | 3.04 | C-8 | 2.61 | D-8 | 2.78 | 8 | 2.95 |

which the phosphate was intimately mixed, then we should expect under the conditions of ordinary field practice that these phosphates would remain undissolved and unfixed for a much longer period of time.

On the basis of this interpretation of the results of the soil analyses, there appears to be no support for the theory, presented earlier in this paper, that the presence of the added lime might result in the wholesale precipitation by calcium of the added superphosphate. For, if such had been the case, the values for phosphate in the soils which received both lime and superphosphate would, if we may neglect the slightly greater absorption of phosphorus from this treatment, have been higher than on those which received superphosphate alone. Reference to Table IV shows that such was not the case. Neither do the data offer evidence that the lime retarded the solution and subsequent fixation of the reverted phosphate, as was thought might prove to be the case. In fact, there was some tendency for soil phosphate to be lower where lime was used in conjunction with reverted phosphate than where the phosphate alone was used. This may have been due to the greater absorption of phosphorus from the limed soil.

## Summary and Conclusions

The availability to sugar cane of reverted and raw rock phosphates was compared with that of calcium superphosphate. These insoluble phosphates were found to be equally as available to sugar cane as superphosphate in the acid, high phosphate-fixing soil used in the experiment. All three forms of phosphate resulted in yields ten times those obtained in the controls. Even when the acidity of the soil was reduced by liming, insoluble reverted phosphate proved to be equally as available as superphosphate.

The effect upon the yield of liming the soil prior to fertilization with phosphate was determined both in the case of a soluble and an insoluble phosphate. Super and reverted phosphates on the limed soil resulted in larger yields than when these phosphates were employed without lime. Lime, in the absence of added phosphate, did not result in appreciably increased cane growth.

The addition of lime to the soil at the rate of 9 tons per acre was not found to adversely affect the quality of the juice.

Attention was given to the possible use of the percentage of phosphorus in the cane plant as an indication of the supply of this nutrient in the soil. Marked differences in the supplies of available phosphate in the soil did not result in differences in the percentages of this nutrient in millable cane. The tops, however, were found to reflect the supply of phosphate in the soil.

The symptoms of phosphate deficiency in the control canes were: (a) lack of normal growth, (b) yellowish color of the leaves, and (c) complete absence of tillering.

Markedly higher values for R.C.M. phosphate at harvest were found in the soils which had been fertilized with raw rock phosphate than in those which had received superphosphate. This is interpreted as indicating that a considerable portion, at least, of this insoluble phosphate was still present in the soil at harvest in much its original form. It is suggested that under field conditions the period required for the solution and subsequent fixation of raw rock phosphate would be much greater. To a lesser extent reverted phosphate was found to resist fixation.

The writer is indebted to the Sugar Technology department for the analysis of the juices. He also wishes to express his appreciation to R. J. Borden, P. L. Gow and D. S. Judd for counsel received and to Wm. SaNing for assistance in conducting the experiment.

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# The Sixth Congress

of the

# International Society of Sugar Cane Technologists

October 24 to November 5, 1938

at

Louisiana State University, Baton Rouge, Louisiana

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By W. W. G. Moir

*December 9, 1938.*

Experiment Station, H.S.P.A.,
Honolulu, Hawaii.

*Dear sirs:*

Since I was sent to the Sixth Congress of the International Society of Sugar Cane Technologists in New Orleans and Baton Rouge, Louisiana, as a representative and chairman of the delegation, I feel it only right that some report or record be submitted of things seen or information secured. The report requested by the program committee of the Hawaiian Sugar Technologists is included herewith, as it contains more details and will save repetition. A copy of the reports of committees and abstracts of papers submitted, which were given each delegate upon registration, is also appended, as well as a pamphlet from the U. S. Industrial Alcohol Company.

The delegation from Hawaii consisted of Messrs. H. P. Agee, W. van H. Duker, C. R. Ferdun, L. D. Larsen, Toru Oishi, S. S. Peck, C. E. Pemberton, O. H. Swezey, Keith Tester, J. N. P. Webster, C. A. Wisner and the writer. Somewhere between 275 and 300 delegates attended the meetings, which probably made it the largest thus far held by the Society. The writer has attended five of the six congresses held by this Society, having missed the Australian gathering. Of those meetings attended, this one was probably the most outstanding insofar as the presentation of papers based on scientific research is concerned. Usually there have been a great many papers on general items of cane cultivation, but at this meeting there seemed to be a dominance of reports on scientific investigations. These were not confined to one or two countries but were presented from every country represented at the gathering. One of the outstanding differences of this congress from those of the past was the preponderance of younger men who enthusiastically, ably and unhestitatingly presented their work to the world for criticism or commendation.

Hawaii has for many years been the envy of other sugar producing countries in the great use it has made of research. Other countries have followed our policies and developed them to suit their particular needs. Instead of finding ourselves still out in front in the race for information on better cane culture and sugar production, we now must admit we are running a race where the other participants are on our heels, and running neck and neck in some matters. These, in general, are the conclusions one must arrive at after listening to the delegates from other countries presenting the results of their investigations.

Eleven years ago, I visited Louisiana and saw a sugar industry that was about to close its doors but which had one ray of hope presented to it in the form of new canes. Today one finds a thriving industry with potentialities of production far exceeding quotas allotted by the A. A. A. In fact, under the sugar control program the industry doubled its output in the five years from 1933 to 1937. Even under the severe control of acreage, as well as quota, decreed for 1939, the crop may again exceed the quota and a large carry-over result. This phenomenal improvement in the state of an industry is almost entirely due to research.

As the result of the foreign introductions and cane breeding work carried on by Dr. E. W. Brandes and his associates in the Sugar Plants Investigation Bureau of the United States Department of Agriculture, together with the cooperation of the Experiment Station at Louisiana State University, mosaic disease has practically been conquered. With the control of this disease, a great stimulation has taken place in all lines of investigation on soils, fertilizers, harvesting and windrowing losses. A new outlook on crop production and hopes for the future have so heartened the planter that today one finds a naturally expanding industry creating rather serious problems for the sugar control program of the A.A.A.

The mainland cane growers will probably be forced to reduce their acreages in cane in 1939. The 1938 crop will fill their quota and produce a reserve from an acreage of about 325,000 acres. It has been estimated by the A.A.A. that 250,000 acres will produce the necessary quota for 1939. If these figures are correct, it will mean a 75,000-acre reduction, or about 24 per cent. This also means that there will be no second ratoons, and that, in turn, means there will be more cover-cropping. This will result in saving fertilizer costs on the plant crop, as well as producing a heavier crop. You will readily see that the chances for a much larger production are very strong and that the A.A.A. control is really necessary to prevent over-production.

Outside of the wonderful return of this industry to a place in the sun through the use of disease-resistant canes, much has been accomplished in cultural and other practices. The severe curtailment of germination in seed and stubble, after the winter dormancy, has been a marked control of crop production. The newer canes have aided in the remedy of this, but the new practice of planting in August instead of October and November will do even more. The better established root and stubble formation from earlier planting aids in withstanding the severe conditions of the winter weather.

With better varieties, fertilizer responses are now secured. These are mainly in ratoon crops. With these heavier-producing canes, harvesting operations have been greatly improved and costs reduced. The excellent use of cheaper and lighter equipment in harvesting operations greatly interested those from Hawaii and serious consideration should be given towards adapting these methods to Hawaii.

While visiting in Colorado, I had the opportunity to become acquainted with some of the field problems of the sugar beet industry. It was most heartening to find that the same basic principles of sugar production found in cane were applicable to beets. Sugar is laid down in greater concentration in the rings of the beet in a sort of hollow, inverted, conical area midway between the center of the beet and the outside layers. The fibro-vascular bundles of the older leaves are connected with the center core while those of the newest leaves are connected with the outer rings. The

rings laid down when sunshine, moisture and fertility are at their optimum are those producing the most sugar. The work of the late Dr. Das has shown that in sugar cane this is true of those joints laid down under optimum conditions. The quality and quantity of sugar produced is materially affected by the vigor of growth, the excess or deficiency of moisture, or the unbalancing of optimum conditions through disease, climate, or nutrition. This year, with heavy, late rains and heavy disease attacks, late growth was secured. Poor sugar storage resulted because of the poor weather and leaf spot disease. The yields of beets were good but the sugar content was low. Many points of similarity exist in the two sugar crops and this makes a visit to the beet area exceedingly interesting. The Grand Lake Water and Power Project now being started will bring irrigation water to these sugar beet growing areas. This will mean a normal crop each year instead of once in two or three. It also means the possible expansion and overproduction in this area.

Pen-feeding both cattle and sheep are very thriving operations on farms adjoining sugar beet factories. Beet pulp, molasses and soybean or cottonseed meal furnish the balanced rations. Cattle and sheep are purchased just before the beet harvesting starts and are sold at the end of the harvesting season. The cooperation, dependency, and mutual benefits secured by these cattle raisers and beet producers should be an incentive to sugar cane growers and ranchers in Hawaii to inaugurate similar practices.

In a discussion with J. B. Trinler, Manager of Central Preston, Cuba, it was found that his company has been having excellent results with pen-feeding cattle with a mixture of yeast, molasses and very fine powdered bagasse, all of which were produced at home.

The great interest shown by delegates at the meeting in the utilization of by-products of the sugar industry—the visit to the International plant of the U. S. Industrial Alcohol Company, and the Celotex plant—and the discussions held with experts on these matters, greatly impressed several of the Hawaiian delegates. More than once our members expressed their hopes that our local industry would embark on the development of more by-products on a large scale and that the Experiment Station be permitted to expand on the present investigations. This work would materially help our industry through these depressing times.

The excellent papers presented by delegates from all over the world gave detailed results of research that has materially aided crop production through disease and pest control, proper nutrition, and cheaper harvesting and milling operations. It is sincerely hoped that these papers will be reviewed in our Station publications and useful data analyzed for our education. It was exceedingly stimulating to see how the rest of the sugar producing countries had so strongly turned to research in the solving of their problems. This also strongly impressed on our minds the even greater need of research at our Station to maintain our existence in the ever keener competition. The heavier and cheaper production in other sugar growing countries, but more especially in those of our mainland domestic areas, makes even greater research imperative if we wish to survive in this economic war. Here's hoping we may ever keep our heads up and lead the way.

Respectfully submitted,

(W. W. G. M.)

This cane sugar congress, which was probably the largest thus far held, was most ably and efficiently organized. Great credit is due the hosts and hostesses for their hospitality and endless efforts to make this the very best congress. The writer feels that they were very successful in these efforts. An excellent change was made in the usual congress procedure so that after a preliminary get-together the delegates took a tour through the sugar section of Louisiana before getting down to the more serious work of listening to and discussing matters presented to the various sections of the society. On this tour each day's visits to plantations and communities showed us again and again the genuine Southern hospitality in all its perfection. During the first two days we visited the International plant of the U. S. Industrial Alcohol Company, the Gramercy Refinery of the Colonial Sugars Company, the Chalmette Refinery of the American Sugar Refining Company, and the Celotex plant of the Celotex Corporation before leaving New Orleans on our Greyhound tour of the sugar-growing parishes, but more especially of the Evangeline country and its bayous.

On one of the days, while still at New Orleans, a visit was made to Reserve Plantation owned by Godchaux Sugars. Several sugar factories were visited by the mill group on the tour, while the field group was taken to field tests on varieties, fertilizer and diseases, and to see general field operations.

To more thoroughly understand the methods and problems of the Louisiana sugar industry, a general but brief survey of history, soils, climate, labor and transportation should first be given.

From the introduction of sugar cane to Louisiana in 1751 down to the present time, one finds a most interesting story of the trials and tribulations of the early French and Spanish pioneers and the many others that have followed them. A chart of the sugar production per year will show you just how the ups and downs of their industry have followed the governmental affairs and disasters that normally befall most any agricultural crop. Probably the greatest and most rapid decline was that in the period from 1922 to 1926 and this was almost entirely due to the ravages of the mosaic disease. Likewise, the most spectacular increase was in the years from 1930 up to the present when resistant varieties, imported or created with the cooperation of the United States Department of Agriculture, have re-established a necessary industry. It can be said without fear of contradiction that without the use of disease-resistant or tolerant varieties the sugar industry of Louisiana would now be a thing of the past.

Louisiana is at best only a sub-tropical country and it is only due to the phenomenal growth secured from these newer varieties in the few good growing months of the year that a crop can be secured. Planting is carried out usually in the fall months of September and October. Ratooning follows the harvesting in November and December. Since wet and frosty weather usually exists up to the end of April, there is really but six to eight months of growing time left to produce a crop. During the months of July, August, and September cane growth is phenomenal. The two great drawbacks to heavy crops are, first the slowness and, second, the lack of proper stooling after the winter dormancy. In ratoons, and more especially in plant cane, this poor germination is a very serious curtailment. A new practice that has become more widespread and very promising is that of planting in August whenever body seed can be secured. This early plant will often be killed down

with the frost in winter but the stubble has become sturdier and better established than that from fall plantings. Long stalks are more often used for seed in contrast to short seed pieces. Depth of planting depends largely upon the time of the year when planting is done—that is, deeper for protection in cold weather.

Fertilization is varied according to soil type, variety, plant or ratoon and to individual likes and dislikes. It has become almost a uniform practice to fertilize ratoons, but not all plant crops are so treated. All fertilization is carried out in the late spring or early summer in one application when some stalk formation is showing. A single application has been found to be as effective as several. The practice of rotating cane with a cover crop, mainly soybeans or cowpeas, between the last ratoon crop and the next plant is almost universal. To those of us from Hawaii, this loss of one year in growing time for the opportunity of growing a plant crop without fertilization seems uneconomical. But with government control of production and much available land, the practice seems to have its merits for Louisiana. Since no second ratoons (A.A.A. decree) may be raised this next year, more land must be fallowed and cover cropping should materially reduce fertilization costs and stimulate heavier production.

In the spring, the first efforts must be directed towards aiding the germination of the eyes on the seed or stubble. This is usually done by the practice of off-barring to allow the heat of the sun to warm up the soil closest to the eyes. After germination has been secured, cultivation is resorted to to maintain proper tilth and control weeds. Many tractor-drawn implements are in use for these processes. The seed is originally planted in a single line on the top of six-foot beds between deep furrows. This is necessary to maintain proper drainage. As cultivation continues the cane becomes more hilled up and, from a steep-sided furrow and a rounded top to the bed at planting time, a change is made to a more rounded bottom to the furrow and a hilled-up row of cane on the top of the bed at the final cultivation. The furrows usually run in the direction of the greatest fall in slope. Since most of the land is so nearly flat it becomes quite a serious problem to secure proper drainage in certain areas. The rows are usually six feet apart and every hundred feet a deeper furrow or drain is installed for carrying away excess water. Cross drains, opening into these, cut the furrows at right angles. These are not much deeper than the furrows and occur at varying distances, depending upon the slope of the land and the extent of the planting. The cane rows are therefore found to be from 12 to 15 inches above the bottom of the furrow at harvest time. This permits faster harvesting operations; first, by making it easier to cut either by hand or by machinery, and second, furnishing a handy location to separate the trash from the cane. The cleaned cane stalks are laid from stubble to stubble on the two crests of adjoining cane rows over a furrow in which there is no trash. This greatly aids the loading of cane without interference from trash.

Deep plowing, that is deeper than 15 inches, is not often found but experiments under way at the plots of the Experiment Station show much better drainage and healthier cane where deeper plowing was tried. Some cover cropping is carried out by planting legumes on either side of the cane row and burying the crop in the spring before the cane closes in. This saves on some weeding. Often the only preparation a cane field gets before planting is the splitting of the old bed in two and the burying of the cover crop in the furrow on either side. After the cover crop has rotted, in

about one month's time, the planting proceeds on the new bed created where the old furrow existed.

Many points indicate that there might be grounds for their claims of the necessity of returning organic matter to these soils. These are (1) light soils, easily dried out, predominate, (2) very little trash decomposition, (3) only one plant and one ratoon crop and, therefore, not much root formation and its resulting decomposition, (4) all trash burnt off after harvesting, and (5) cold, wet weather part of the year so that organic matter cannot be turned into a useful material during part of the year and probably too rapid production at other times.

It must be remembered that yields of from 15 to 35 tons are the crops that are produced on these lands in the short growing season.

Much of the crop must be windrowed before the grinding season is over because of the fear of killing frosts. Not all varieties keep well in the windrow and not all varieties mature early enough for early harvesting. At the present time, C.P. 28-19 is the favorite for early harvesting but is rapidly being displaced by C.P. 29-320. Co. 281 is still the favorite cane for windrowing as it keeps remarkably well. Mosaic, however, is taking a terrific toll in this variety. C.P. 29-116 is a late maturer but does not windrow as well as Co. 281. Co. 290 is quite a favorite in black soils and C.P. 28-11 in low, wet lands. Both canes, however, are easily flattened with wind. C.P. 29-320 is very resistant to mosaic and will readily recover if infected material is planted. However, it is susceptible to chlorotic streak. C.P. 28-11 and 29-116 are resistant to root-rot troubles, while 29-320 is intermediate and Co. 281 and C.P. 28-19 susceptible and only succeed in light, well-drained soils.

To get a general idea of the soils of the sugar belt, a few excerpts from the abstract of the paper by O'Neal and Hurst on "The Soils of the Sugarcane District of Louisiana" are quoted herewith:

> The soils of the sugar cane district of Louisiana are largely of alluvial origin and have been derived from rich sediments brought down by the Mississippi River and its tributaries during periods of flood.
>
> For the purpose of correlation, the materials thus deposited were separated according to origin and certain topographic and physical characteristics into the following five major divisions: (1) Mississippi alluvium, first bottom soils; (2) Mississippi alluvium, terrace soils; (3) Mississippi-Red River sediments; (4) Red River sediments; and (5) Coastal Prairie sediments of the Gulf Coastal Plain.

These five groups of soils have been again divided into several soil types and named as follows: Group (1) Yazoo, Sharkey and Muck, (2) Lintonia and Olivier, (3) Franklin, (4) Yahola, and (5) Iberia. These differ in pH, movement of water, chemical composition, fertilizer requirements and physical characteristics.

Through the study of these soils in detail, as shown in the paper referred to above, fertilizer experiments have been installed and better fertilization policies have resulted. The newer canes have shown a greater response to fertilization and with the increased yields per acre it has become almost a universal practice to fertilize ratoon crops with nitrogen fertilizers—mostly nitrate of soda and calcium cyanamid. In the coastal plain soils, which are alluvial soils laid down under salty water conditions, somewhat similar to those at Kekaha, there is a distinct response to potash. In the more acid soils (4. — 6. pH) of the older types, responses to both phosphates and potash have been noted. The amounts of plant food used are very small when

compared with Hawaiian practices but are quite reasonable when considered in connection with the very few months of growing weather available.

As mentioned above, the control of cane diseases, and more especially mosaic, is of primary importance to the industry. The exceedingly interesting research carried out on the various strains of mosaic, their different effects on varieties, their effect on each other and their control, is probably one of the most outstanding things seen and discussed at the congress. The control of root rot, of red rot and the research on windrowing losses are all excellent accomplishments shown us while at the Houma Station of the United States Department of Agriculture. Varieties are introduced from the Canal Point Station in Florida and the remarkable accomplishments of these newer canes speak very highly of the work carried on by Dr. E. W. Brandes and his associates in the Sugar Plant Investigations of the Bureau of Plant Industry, U.S.D.A.

The crop is harvested by hand, either by day work, by the ton, or by the "running acre." The day work rate as set by the A.A.A. is $1.50 per male and $1.20 per female. The per ton rate is set at 75 cents by the A.A.A. In the other method, or task work, the rate varies with yield and variety but it is set for a specified length of row about 210 feet in length. Thirty-five rows six feet apart and about 210 feet long make an equal-sided acre, and each line is called a "running acre." The rates vary from 45-65 cents per "running acre." By the task method, many good negro cutters make around $2.00 a day, or slightly more, cutting from 3½-4 tons of cane. Much less is cut by the other methods. Cutting costs are very much higher in Louisiana than in Hawaii. However, the reverse is the case in loading costs.

The most universal method of loading is by the Castaganos, or similar, loaders into wagons. A double self-tripping chain sling is laid in each wagon and the grab loader gathers up bundles of cane weighing a hundred to two hundred pounds and lifts them into the wagon. When there are about 3 tons in the wagon, the chains are fastened and the wagon hauled to a loading station. At the loading station, these slings are lifted out and the large bundle is bound more tightly. Several of these large bundles (about 3 tons each) are loaded onto a trailer or truck and hauled to the mill. At the mill yard, huge crane unloaders lift these bundles onto a pile or onto the unloading platforms next to the carrier. At this point, the chains are removed by tripping the sling. Sufficient cane is piled at the mill during the day to run the factory at night. Huge piles from 30-60 feet in height adjoin the carrier and cover considerable area. The first impression one gets of this procedure is that the cane must become too old in these piles. We were assured, however, that these were cleaned up every 48 hours at the latest which hardly seemed believable. The huge cranes have grabs similar to our harvesting grabs for taking the cane over onto the carrier platform. The costs of loading the cane and delivering it to the main line railroad loading stations do not exceed 30 cents per ton and more often are nearer 20 cents than 30. The railroading to the mill is expensive and usually adds another 20-30 cents per ton, making the total harvesting cost per ton delivered to the mill around $1.25. Where the trailers deliver their loads of 5 to 7 bundles (14-18 tons) to the mill yard, the costs of harvesting per ton are lower. This usually happens for areas within driving distance of the factory. These trailer trucks are usually of the semi-trailer type with Ford or Chevrolet hauling units. The trailers constructed by several local concerns are of excellent construction and stand up well. These trailers

cost in the neighborhood of $500.00 and with an $850.00-$900.00 truck-hauling unit the total cost is under $1,400.00. As mentioned above, these readily haul from 14-18 tons per load and travel at a fairly fast rate of speed. These semi-trailers usually have about the following dimensions—27′ x 8′ x 5′. Some of the best that we saw were made by the Thompson Machinery Company at Labadeiville and should make an excellent piece of equipment for any of our plantations wishing to haul cane on their more level fields. Hydraulic brakes may be installed on them for a small amount extra and the trailers used on heavy grades.

The Castaganos loader, and others of a similar type, are motor driven but are usually hauled around with a team of mules. A small tractor (either Allis-Chalmers or Farmall) will haul 2-3 rubber-tired wagons (2 wheel) and the loader will keep three or more of these "trains" going. At one place we noted a loader with its operator, and a driver for the 4 mules, working with 3 tractors (3 drivers) and a ground crew of 4, with 1 man on the wagon being loaded, or a total of 10 men loading about 400 tons a day. This would compare very favorably with our own operations if all track laying, hauling and loaders were included in arriving at an average tonnage per man. The rubber-tired, all steel wagons sell for from $300.00-$400.00 and weigh a little less than 1 ton.

After harvesting is completed, the trash is burnt off and the field left to ratoon. Sometimes the soil is cultivated but not as a regular practice until the following spring. Where cane is windrowed before being loaded, the leaves are left on and the whole covered over. Later these canes are dug out, topped and cleaned for harvesting operations. A very novel and successful machine was in operation doing this particular job. There were many points about it that might be used in a cane harvesting machine.

Another interesting machine was the Wurtele cane harvester which was doing a fair job of cutting, topping, and bundling long stalks of cane without stripping off much of the dead leaves. It was working successfully in a 30-ton crop of standing cane.

Milling operations were not often observed by the field group but an opportunity was given the writer to see the Munson cleaner in operation and it seemed to be doing a fair job. The feeding of the short pieces into the crusher seemed to be difficult.

Now an attempt will be made to mention the more outstanding papers presented and consider the points that would be of practical value to Hawaii. Since there were over 135 papers presented to the congress, it will be next to impossible to discuss more than just a small share of them. The twelve delegates from Hawaii divided themselves among the various sections so that someone was present at almost all the sessions held. The papers were divided into the following sections for discussion: pathology, varieties, field and soils, entomology, technique of field experiments, and milling. The writer attended mostly the discussions on field and soil problems, with an occasional visit to those on pathology, experimental technique, and varieties.

In the papers on pathological problems, those on mosaic certainly commanded the most interest. As mentioned above, the work on the various strains of mosaic has been so well carried out that it makes one realize how complicated a study of such a cane disease may become. The mild strains of mosaic secured from Hawaii

were shown to be very much less harmful than those in Louisiana. This is an excellent example of how necessary are the quarantine measures we are maintaining in Hawaii. Healthy seed and roguing are still the best control measures. An interesting paper was presented that tended to show that soils or soil treatments had a marked effect on the severity of mosaic. The inoculating of young seedlings with the various strains of mosaic for determination of immunity and resistance is a very much worth while adjunct to cane breeding operations. Papers were presented to show similar testing for resistance to other cane diseases in seedling propagation work. The work in the Philippines on the transmission of Fiji disease by all the stages of the cane leafhopper makes us think all the more of the troubles we are threatened with when plane service is inaugurated to the South Seas. An interesting abstract on *Pythium* is inserted here.

In a series of greenhouse and field experiments carried out during 1936–38 at the Louisiana Experiment Station at Baton Rouge, Louisiana, the development of corn and sugar cane plants was followed in different soil types, at different pH levels, at different temperatures and under different nutrient conditions with particular reference to the effect of these variations upon the action of *Pythium* organisms attacking the roots and upon the action of Trichoderma organisms attacking the *Pythium*.

Under the conditions of the experiments, low temperatures favored the destructive action of the *Pythium*. Modifications of the pH level were without appreciable effect. The application of nitrates was accomplished by an increase in root rot. Treatments with high phosphates were accompanied by a reduction of root rot. In general, however, neither the nitrates nor the phosphates appeared to have any pronounced effect upon the demonstrated antibiotic action of Trichoderma against *Pythium*. A strain of Trichoderma obtained outside the state proved more effective against *Pythium* than most of the strains obtained locally from sugar cane soils.

The control of seed piece rot and the stimulation in germination from using such materials as Ceresan were discussed in a paper from South Africa and the results compare favorably with those secured on Kauai.

Other pathological papers were presented giving general resumés for different countries, and discussions on such diseases as sclerotic disease of sugar cane in Formosa, red stripe in Brazil, red rot in Louisiana, gumming in Queensland and Mauritius, and cytospora rot, stubble deterioration, and rhizoctonia in Louisiana.

The papers on varieties were not as numerous as in the past, as many of the detailed discussions on breeding and selection have been so thoroughly covered in past proceedings. Those of more importance were on the subject of breeding for disease resistance and especially that for mosaic and gumming which were mentioned above. A few on taxonomic, and other characteristics, were presented. Most of those presented from Louisiana clearly showed the exceedingly great importance breeding has been to the return of their local industry to a place in the sun. A most interesting paper by Bell of Queensland showed that "the making of second selections of seedlings on the basis of comparative vigor of 6-10 stool plantings from original seedlings was fundamentally unsound." A paper was presented and many pictures were shown of the crosses between sugar cane and bamboo in India. In the writer's estimation, the evidence is not sufficiently strong to prove that such crosses have been culminated.

In the section on field and soil problems, the two matters will be discussed separately. A paper presented by representatives of the A.A.A. on sugar control programs and their effect on the Louisiana sugar industry showed how serious

these measures may really become. In the discussion following the paper very pertinent questions were not answered by the authors and thus the opportunity for a lively discussion fell by the wayside. A few general papers were presented on the following points: interplanting sugar cane to paddy rice; cane cultivation in Mauritius; flood fallowing sugar cane soils; double versus single planting; some aspects of drought resistance; cultivation by rubber-tired tractors; windrowing; transportation; deep tillage work with gyrolettes; drainage of peat soils; and mechanical harvesting in Hawaii. One paper on "Resistance to inversion of sucrose in harvested sugar cane in Louisiana" by Lauritzen and co-workers at the Houma Station was most interesting and the abstract is presented herewith:

> The inversion of sucrose in harvested sugarcane in Louisiana is influenced by water content and change in water content resulting from prevailing environmental conditions such as air temperature, relative humidity, and air movement and by such factors as temperature, nutrition, maturity, invertase activity, variety of cane and some unknown factors.
>
> All varieties are resistant to inversion under certain environmental conditions and some varieties under environmental conditions that are normally favorable to inversion.
>
> The varietal response to environmental conditions favorable to inversion is characteristic and constitutional.
>
> The response in certain varieties is not correlated with the invertase content of the stalk and must involve in certain resistant varieties some inhibiting factor independent of the invertase content.
>
> In a given variety grown under given conditions the sucrose content of the stalk is an indication of maturity and thus may be an indication of resistance or susceptibility to inversion. In cane grown under different conditions sucrose content may not be an indication of resistance or susceptibility. Between varieties sucrose content is not an indication of resistance or susceptibility.
>
> There are indications that the varietal characteristics relating to inversion are transmitted from parents to offspring.
>
> The development of resistance to inversion of sucrose in sugarcane is of immense economic importance to the sugar industry wherever sugarcane is grown.

A paper on the "Behavior of Sugarcane to Length of Day" was mostly in connection with flowering and should be of some interest to cane breeders. The windrowing machine by Munson, discussed in the first part of this report and in one of the papers, should materially aid the industry in lowering harvesting costs. Most all windrowing starts on November 15th, and a man may windrow from ¼-½ an acre per day by hand. The Munson machine will cover considerably greater area per man per day. Cane often remains in this windrow for 50 days. The other method of research towards reducing costs and losses in windrowing is the breeding of canes better able to stand this severe treatment. Co. 281 is still the best cane for this operation but since it is being so severely damaged by mosaic greater efforts are being made to find something better.

Four excellent papers on the soil problems and types of Louisiana were presented and made use of by the writer in describing the soils in the first part of this report. These showed the variations in physical characteristics and chemical analyses between the several soil types. Considerable variations were noted in attempts to correlate soil analyses with response to fertilizer treatment and to analyses of cane juices. In some soils correlations were good, while others showed none at all.

One paper presented from South Africa gave criticisms of the Hawaiian rapid chemical methods of analyses. Excellent papers from Queensland by Kerr and von

Stieglitz, together with those mentioned above and with comments made by delegates present at the discussions, very clearly illustrated the diversity of problems and conditions in different cane growing countries. The writer pointed out at the meeting that where methods were satisfactory and correlations were secured in any one country it was asking too much to expect these methods and correlations to be true in another country. The important point brought out was that if any methods were helpful to our better understanding of proper nutrition it was of little, if any, importance if these same methods were unsuccessful in another country. As pointed out by one of the most able investigators present at the meeting, it was much more important to put your facts into practical application on your own soils than to rush into print so someone else might find fault with your methods. But, above all, he added: "Be sure that you yourself are sufficiently critical of your own methods so that there is no self-deception."

A paper on water culture work with phosphate deficiency in Formosa presented some interesting facts. References were made to other papers published by the same authors—Saito and Kenjo—on nitrogen and potash deficiencies, and these should be secured and studied together before comments can be made. The writer would like to suggest that these be reviewed and discussed in *The Hawaiian Planters' Record* or the *Director's Monthly Letter* and compared with Hawaiian results.

In the experimental technique section much was said on sampling both cane and soil for representative data. Once again the methods satisfactory for one country may not be that for another. The portable weighing apparatus used in experiments in Louisiana warrants a trial in Hawaii and especially so since size of plot has nearly always been related to the harvesting equipment and the ability to weigh all the cane grown.

The Report of the Committee on Technique of Field Experiments together with the papers by Borden; Kerr; Arceneaux, Belcher, Gibbens and Stokes; Holmes and O'Neal; and Williams and Follett-Smith, all brought out the differences of opinion on experimental layout and interpretation of results. Some of these seemed to be giving too much consideration to the actual data secured and not sufficient to the practical considerations of the things that may have happened to produce those particular results. On the whole, these papers are of considerable interest and worth greater study and review by someone more versed in their details than the writer of this report.

The entomological papers and discussions will be more ably handled by C. E. Pemberton and those on milling by S. S. Peck.

A most interesting abstract of the paper on "The Cell-sap concentration of sugar cane varieties in relation to their resistance to the attack of white leaf louse" by Yamasaki and Arikado, is presented herewith:

Tests of the cell-sap concentrations in the leaves of twenty varieties of sugar cane, half of them resistant and half of them susceptible to the attack of the white leaf louse, disclosed the fact that all of the cell-sap concentrations in the susceptible canes were appreciably higher than in the resistant canes. Further tests of infested and non-infested leaves gave similar differences. The minimum critical concentration at which cane leaves appeared subject to attack was about 4.5 (Ref. Brix). In addition to varietal differences in cell-sap concentration, it was observed that the addition of water by rain or irrigation reduced the cell-sap concentration. The results suggest possible control by choice of varieties and irrigation where indicated, cell-sap concentrations being taken as indices.

In the milling section, the following two papers seemed of particular interest to the writer: "The use of phosphoric acid in cane sugar manufacture and refining" by George P. Meade, Manager of Gramercy Refinery of the Colonial Sugars Company, and "Developments of J. J. Munson for improving conditions of sugar mill operations" by E. L. Denis, Consulting Engineer of Godchaux Sugars, Inc.

On the whole, the meeting and tour did much to stimulate our interest in many ways but mostly in regard to harvesting equipment and disease control. It is hoped that more members of our local society will become members of the International one and secure the printed proceedings for a more thorough study. The writer wishes to thank you for the privilege of presenting this report and hopes there may be something of interest in it. However, he wishes to clearly point out that the above figures and comments on operations in the Louisiana cane belt are subject to criticism. It hardly seems possible that an absolutely accurate picture could be secured in so short a visit. Apologies are offered for the mistakes, if they exist, and to anyone who may have been hurt by the writer's comments.

# Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
SEPTEMBER 26, 1938 TO DECEMBER 5, 1938

| Date | Per pound | Per ton | Remarks |
|---|---|---|---|
| Sept. 26, 1938.. | 3.05¢ | $61.00 | Cubas; Philippines. |
| " 30....... | 2.99 | 59.80 | Philippines. |
| Oct. 5....... | 3.02 | 60.40 | Philippines; Puerto Ricos. |
| " 6....... | 3.0833 | 61.67 | Puerto Ricos, 3.08; Philippines, 3.10; Cubas, 3.10, 3.07. |
| " 7....... | 3.135 | 62.70 | Philippines, 3.15; Cubas, 3.12. |
| " 14....... | 3.10 | 62.00 | Cubas. |
| " 18....... | 3.05 | 61.00 | Cubas. |
| " 21....... | 3.10 | 62.00 | Cubas. |
| Nov. 1....... | 3.08 | 61.60 | Cubas. |
| " 3....... | 3.05 | 61.00 | Cubas; Philippines. |
| " 22....... | 3.00 | 60.00 | Puerto Ricos. |
| Dec. 5....... | 2.85 | 57.00 | Cubas. |

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